RECORDS

OF

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RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 1.] 1890. **[February.**

ANNUAL REPORT OF THE GEOLOGICAL SURVEY OF INDIA, AND OF THE GEOLOGICAL MUSEUM, CALCUTTA, FOR THE YEAR 1889.

PENINSULAR INDIA.

Messrs. Foote and Lake.

MADRAS PRESIDENCY.—*Transition and Vindhyan Series.*—The examination and mapping of the Dharwar series has been steadily followed out by Mr. Foote.

Auriferous Series.

In this quest, he took up the survey of the Harpanahalli section of the Dambal-Chiknayakanhalli band and carried it down into the Mysore Territory. The reputed auriferous tract around Chiggateri received very special examination, some time being spent in testing the character of the alluvial soils brought down by the different streams in that quarter. In one of these, flowing northwards from the Jajkal Gutta, very favourable shows of coarse and good coloured gold were washed; while in several other streams fair results were obtained; all which leads him to the conclusion that, though the many blue quartz reefs examined by him did not show any free gold, this field is well worthy of systematic prospecting.

Iron and manganese ores of Sandur.

At the request of the Government of Madras, Mr. Foote supplied a very full note on the economic geology of the Sandur State, where, perhaps, the most conspicuous features are the great beds of hæmatitic iron ore which should afford an enormous and practically inexhaustible supply of iron. The disappointing feature, however, is the absence of any form of fuel except such small quantity as can be obtained from the local jungle; and were it not for this—even in the face of the splendid iron tracts in the Salem, and to a lesser extent in the Kurnool Districts—the field might be, as Mr. Foote describes it, the greatest iron-yielding centre in Southern India. The Singareni coal-field, now coming into such favourable notice, is within railway reach, but, it is to be feared, at too great a distance; while its own immediate stores of iron will naturally be the first in the field of iron industry.

On the southward slope of the western range of the Sandur hills, Mr. Foote discovered an important argillite formation very rich in nodular oxide of manganese, or pyrolusite, capable of being easily mined by open workings on a large scale

Diamond-bearing rocks.

The area of the Banaganpilli beds, or diamond-bearing formation, was extended somewhat by the recognition of a coupie of outliers well to the north of Guti, in Western Kurnool. These were found to have been worked to some extent by the old miners. The finding of them so far out on the gneissic area west of the main tract favours Mr. Foote's suggestion that the diamonds found lately within the gneissic tract are merely the residue of the debris from once-existing western extensions of the Kurnool Formation. I am, therefore, still of opinion that if the diamond industry is to be a success in Southern India, exploitation will have to be made within the area of the group of rocks known by the numerous old workings as having yielded diamonds; that is, in the Banaganpilli beds, the area and outcrops of which are very clearly laid down on the maps issued, or which can be issued, by the Survey. A memoir on this western part of the Kurnool District only waits the engraving of an illustrative map; while considerable progress has been made in preparing parts of the memoir on the Bellary District which should issue on the completion of the survey by the end of the present working season.

West Coast Survey.

Tertiaries of the West Coast.—Mr. Lake was removed early in the year to the Malabar District, with a view to closing up the blank still disfiguring our general map of the Geology of India on that side of the Peninsula. The call, however, for coal and oil exploration in Baluchistan having become imperative, he was transferred to the north-west frontier party; and thus the survey of the Malabar and Cannanore country is indefinitely postponed. A considerable tract, extending over some 1,000 square miles in South Malabar, was surveyed, the results of which will be given in Mr. Lake's forthcoming memoir.

Laterite.

The geology of this side of the country is mainly interesting in the extraordinary development of laterite, the origin and occurrence of which still requires considerable research; though Mr. Lake's survey of so much of it has brought to light many fresh data of considerable scientific value.

Smooth-water tracts of Travancore.

After the close of the working season, and just as the south-west monsoon was expected to be in full force, Mr. Lake was sent down to Alleppy to study the action of the famous smooth-water tracts, or mud banks, which present so strange a feature on that coast. As usual, when an opportunity occurs for reviewing peculiar physical features of this kind, the monsoon was not so strong as might have been expected; but such effects as Mr. Lake could study were enough to explain in great part the features displayed. I had myself already ascertained that there is a sensible amount of oil contained in the mud of the banks underlying the smooth tracts around which the rollers from the south-west break in greater or less force during the monsoon; and had ventured to suggest that the stirring up of such oleaginous mud, and possibly the increased discharge of oil at the stormy period, might have some very decided influence in the smoothing of the waters. Mr. Lake's study does not, however, lead him to consider that the oil has more than a partial influence in this direction; the main cause being attributable to the increase of the density of the water when mixed with the mud. The discharge of oil seems to be increased, a thin coating of it being clearly recognizable in patches on the surface of the water; but this is altogether insufficient to encourage the hope I had formed of there being any deep-seated source of oil warranting exploration by boring into the tertiary lignitiferous deposits known to underlie many points at this and other spots on the Travancore, Cochin, and Malabar Coast. A paper by Mr. Lake appears in the present number of the Records.

Messrs. Mallet, Bose, and Sub-Assistant Kishen Singh.

Closing of Balaghat Survey.

CENTRAL PROVINCES.—*Transition; Bijawars.*—Notwithstanding the demand for distribution of the Survey as much as possible on the examination and exploitation (where possible) of regions containing minerals or rocks of economic value; it would have been obstructive of all progress along purely geological lines, which are after all essential to a correct diagnosis of the mineral extensions and capabilities, to have abruptly left off any particular following out of such formation as was in progress in the commencement of last season's work. I therefore deemed it expedient to keep Mr. Bose, with whom was Mr. Sub-Assistant Kishen Singh, at work at the Bijawars and Vindhyans of Balaghat. My ultimate design in working out the run of these formations, is to connect them with the Vindhyans and the Dharwar Series of Madras, the latter formation being, by all the evidence before us, probably of the same age as the Bijawars. Certainly, these two, the Dharwars and Bijawars, are characterized by their being each metalliferous formations in Madras or in Central India. The Balaghat Bijawars (or Dharwars) are conspicuous for their development of iron ores; though they are also known as carrying copper and lead ores which were mined long ago with a perseverance which might lead prospectors to form most hopeful views of further lodes. Mr. Bose completed his survey from the northwards (in the Salitekri hills of the Mundla and Bilaspur Districts) down to the Nagpur-Bengal Railway line: thus leaving his geological boundaries ready to be taken up at any future time at a point within easily communicable reach. Full progress reports and maps of his and Kishen Singh's work have been placed on record.

Materials for Pottery, Jabalpur.

The efforts of the Survey have, however, been directed to the localization of materials needed for pottery works in the Jabalpur District. This question of utilizing the clays and coal occurring in the neighbourhood of Jabalpur has received attention of all kinds, and on several occasions during a period of many years; having been, I believe, mainly originated and fostered by Mr. Glass, the present Chief Engineer to the Government. At the urgent request of the Chief Commissioner, a final and exhaustive examination was made by Mr. Mallet, which has led to the very satisfactory result of works being, or about to be, started at Jabalpur by Messrs. Burn & Co. of Calcutta. Mr. Mallet's report, which appeared in the Records for last May, gives details of the occurrence and abundance of all the materials required, in and around Jabalpur, or within convenient distance of the Umaria Colliery.

Enquiry into soapstone or steatite.

A further very interesting series of experiments was made and reported on by Mr. Mallet, concerning steatite from various parts of India, in response to a demand from England through Her Majesty's Secretary of State for India; when it was ascertained that the material associated with the Bijawar dolomitic limestone of the Marble Rocks near Jabalpur comes very close to the standard of the steatite at present utilized in the manufacture of gas-burners in England. Mr. Mallet's Note on Indian Steatite appeared in the same number of the Records, and is the result of a very elaborate testing of samples of steatite from the Madras Presidency, Central Provinces, Rajputana, and Burma. The result shewed, as I had long anticipated from my acquaintance with the source of the very fine form of the mineral known as "Bulpum" in common use as a writing chalk over the Madras Presidency, that the Kurnool District stands first in the likelihood of a production capable of successfully competing with the comparatively costly material now imported from Germany for gas-burners in England. The opening up and exportation of this new product from India must necessarily be attended with considerable difficulty and hazard, mainly, perhaps, owing to the difficulty of obtaining men skilled in the selection of proper stone. The quarrymen of the country are, however, a very teachable class who can soon appreciate the points of any stone for which there is a steady demand. The fact remains that the stone occurs sufficiently pure and workable, sometimes within easy reach of railways; so that, after making liberal allowances for supervision, royalty, railway, shipment, and incidental expenses, it appears clear that the good steatite from every locality ascertained in this investigation, except those from Burma, may be delivered in London at prices far below that now paid for the continental stone.

Mr. P. N. Bose's exploration of the manganese deposits near Jabalpur was referred to in the annual report for last year; since then his second notice, or geological sketch of the manganiferous iron and manganese ores of Jabalpur, was published in the Records for November last.

Messrs. P. N. Bose, F. Noetling, and Sub-Assistant Hira Lal.

Revival of search after gold.

BENGAL PRESIDENCY.—*Transitions ; Dharwar Series.*—It was naturally to be expected in the development of the gold industry in the Madras Presidency, that speculative and prospecting interests should in time be turned to all the known tracts giving any indications of gold; and thus the belt of country in Chota Nagpur, which from time immemorial has been known for its native gold washings and occasional finds of decided fragments of gold, has again come into notice through the formation of a syndicate to work the neighbourhood of Sonapet. The Survey was asked for assistance in further reporting; but considering what has already been done by our former colleague Mr. Ball, as described in his Memoirs and in the Manual of the Geology of India, as well as that all the evidence goes to show that the rocks of the country belong in all probability to the Dharwar series of Madras, it does not appear that there will be any use in further geological reporting. The time has, in fact, come for exploitation; and this, in the case of gold, can be best carried out by private enterprise.

Dr. Noetling, however, took the opportunity during the Pooja holidays of looking up the country, and has thus been enabled to send in a report which adds somewhat further to the knowledge we have of this region. His note will be published in the next number of the Records.

Lower Gondwana.—The defining of the eastern limits of the Chota Nagpur coal-fields, by Mr. Sub-Assistant Hira Lal, was finished by the end of the working season; so that there is now a full and careful record at head-quarters of the coal capabilities of this rather wild, and at present not easily approachable, tract of country. Hira Lal also added materially to the filling in of the general geological map of India by mapping in some rather extensive eastern outliers of the Deccan Trap of which we were unaware: thus bringing the connecting links in the argument for the possibly Deccan Trap age of the Rajmahal Traps into closer view.

Rajmahal coal.

The borings which were arranged for by the Government of Bengal, in the Hura field on the western edge of the Rajmahal Hills, have been carried out, but without any satisfactory results as to the quality of the coal found. Three borings were put down, the first of which, within a reasonable distance of the old outcrop workings near Dakaiti, gave no satisfactory show of coal. The second, somewhat further to the east, struck the floor (gneiss) of the field at 297 feet, having passed through several seams of carbonaceous shale and two of poor coal. A third boring showed a certain improvement and distinctness in two of the coal seams; one of 4 feet in thickness at 113 feet, and a second of 16′ 6″ at 228 feet. The percentage of ash is still, however, too large. It was then decided to put down some further borings to test these seams further to the east. I have lately pointed out sites for these, and they are now in active progress.

Darjeeling coal.

The Deputy Commissioner of Darjeeling has, with a wonderful perseverance, kept up the interest in the Darjeeling coal, notwithstanding our continued reports as to the poorness and crushed condition of the outcrops from which samples have been taken and sent down to the Survey Laboratory. At his urgent request, however, opportunity was taken of Mr. Bose's temporary stay on the hills, for the examination of the metalliferous indications in the northern part of the district; and later on, as the season suited, attention was turned once more to the coal outcrops eastward of Teendaria. With these latter, Mr. Bose has been so successful as to have found exposures of two thick seams, one of more than 20 feet, in the ravines to the southward of Kalimpong. Coal of both tertiary and Gondwana age occurs along the foot of the hills; but it is satisfactory to learn that these thick seams belong to the true Indian coal-measures, and that the assays so far as they have been tried in our Laboratory, are fairly satisfactory. The coal is still much crushed and difficult of extraction in large pieces, while the surface samples collected do not cake. The results are, however, so encouraging that every effort should be made to test it practically in the field: and, to this end, Mr. Bose is placed there during the present field season to carry out a series of excavations, as well as experiments in the field as to the coking powers of the excavated coal. The enquiry is at the same time being most cheerfully aided by Messrs. Burn & Co. of Calcutta, who have most obligingly placed a small press at Mr. Bose's disposal for experiments in the way of moulding the crushed coal into briquettes. The region in which this coal occurs is an exceedingly difficult one to examine, being in the midst of dense jungle which can be considered healthy for only a few months in the year. I am glad to record my appreciation of the very enthusiastic manner in which Mr. Bose is engaging in the exploration; while it is gratifying to note that he is meeting with all that assistance and kindness so uniformly afforded by planting proprietors and managers, who in so many cases open up country which might otherwise be almost inaccessible to the geologist. The working of coal in a region of such crushed and overturned strata as that of the outer slopes of the Himalayas must always be attended with considerable difficulty and even danger, let alone disappointment in the breaking-off and nipping-out of seams, owing to fractures and foldings in high-dipping strata; but the outlook for a supply of fuel in the Duars does at the present time seem to be promising, and the credit of clearing it thus early is certainly due to Mr. Paul's determined faith in the extension of the coal so poorly shown in other parts of his district.

EXTRA-PENINSULAR INDIA.

Messrs. R. D. Oldham, E. J. Jones, C. S. Middlemiss, P. Lake, and Sub-Assistants Kishen Singh and Hira Lal.

BALUCHISTAN AND THE PUNJAB.—Mr. E. J. Jones was despatched early in the year to take up a further examination of the Khost coal, or rather of the outcrops in the Sharigh Valley, on the results of which I gave an abstract report in the Records for August last. As is the usual habit of coal of that age in this region, the seams are very thin and so situated that it is extremely difficult to form a fair estimate of the available amount of fuel, or, indeed, of the most profitable mode of extraction. His search resulted in the conclusion that the Khost seam is still the one on which any reliance can be placed as a possible profitable source of fuel for that section of the frontier railway. He formed what may be considered a reliable estimate of 565,000 tons of coal as likely to be profitably extracted; although there is little doubt that considerably more coal is actually hid away in the depth of the hill ranges to the southward of the station. The difficulty lies, of course, in the working of so thin a seam, lying as it does at an angle which brings it more under the form of excavation of a mineral lode than of a bed, but this is a problem which can only be satisfactorily taken up by colliery engineers.

Baluchistan coal and oil.

Since then, a thorough examination of the coal and oil conditions of the tract traversed by the railway between Sibi and Quetta has been determined on by the Government of India; and a party of the Survey under Mr. R. D. Oldham is now engaged on the work. Several more outcrops of coal have been examined, but they are all thin and more or less high-dipping and, so far, such as for a long time can be best worked by some form of outcrop excavation, and by the utilization of local labour in excavation and carriage rather than by the adoption of any expensive system of colliery work or transport.

The recognition of the locale of reservoirs of mineral oil and of their productive possibilities, judging from the 'shows' on the surface, or from the following out of particular zones or tracts of strata, is still to a very great extent about as puzzling a problem as can come before the geologist. It is, in fact, a problem which in a great many cases is still only solvable on what may be called empirical data. Within the last month, however, some rather cheering news in favour of legitimate geological reasoning and following out of formational indications has come from Mr. R. D. Oldham, who has recognised 'shows' near Spintangi on the line of railway itself. These exhibitions do not come up to the standard displayed at Khatan, but they are enough to warrant the expectation of the existence of a reservoir of oil beneath the locality, though, perhaps, at a considerable depth. Mr. Oldham's report on this promising find is expected shortly.

The Salt Range.

While on tour early in the year, I revisited the Salt-Range region with Mr. Middlemiss, partly with a view to finding corroborative evidence of Dr. Warth's recognition of *Trilobites* in the 'Neobolus Beds, a notice of which is given in the Records for August last.

Mr. Middlemiss, having just concluded his survey of the lower Himalayas between Haldwani and Hardwar, brought with him all the experience gained in his study of the remarkable geotectonic features of that region, balanced as it is by his admirable training in the later treatment of geological physics, and his excellent observational powers; so that it is not surprising that we found certain new features and conditions of the Saline Series itself, and its relation to the other formations which demanded a resurvey of portions of the range. Even on geological grounds alone, the re-examination was imperative; but it has its value as bearing on the conditions of the formation in which the coal seams of Dandot occur, and on the closer determination of the formations supposed to hold any reservoirs of oil in the Punjab and Baluchistan.

This examination of the ground has, therefore, been entrusted to Mr. Middlemiss, with whom is associated Mr. P. N. Datta. It will probably be finished by the end of the present season.

Messrs. R. D. Oldham, C. S. Middlemiss, and P. N. Datta.

HIMALAYAS.—*Palæozoic and Mesozoic.*—The work stated as in progress in my last annual report was brought to a close at the end of last working season. The result of Mr. Oldham's work in the Dehra and Simla portion of the lower Himalayas will appear in a memoir as soon as time can be spared from the more pressing investigations in Baluchistan. In the meantime it is satisfactory to know that we have now a full record of the geology, on a more detailed scale of map, of the most frequented part of the Himalayas, and that there is sufficient new evidence here and in the Haldwani-Hardwar tract to help on in some measure the exhaustive study of this great range which was initiated and carried on with such ardour by my predecessor, Mr. Medlicott. The publication of Mr. Middlemiss' Memoir on the Physical Geology of the Sub-Himalaya of Garhwal and Kumaun was delayed in order that the full survey of the ground might be completed down to the Sarda river, or frontier of Nepal, and on account of the engraving of the illustrative map. In this south-western extension of the work, he was enabled to study and bring into notice the gypsum of the Nehal Nadi, Kumaun, which should become a very useful and paying product in that region. A short paper on the occurrence of this gypsum was given in the May number of the Records.

Gypsum.

Mr. LaTouche.

Coal.

ASSAM.—*Cretaceous and Tertiary.*—During the last year more detailed reports were called for on the coal-fields of the Khasia and Jaintia Hills, and these have been furnished by Mr. LaTouche. His reports on the Cherra Poonjee and Lakadong coal-fields, illustrated as they are with plans on a scale of 400 feet to the inch, leave their future working entirely in the hands of Colliery engineers. The geological survey of them is completed: no exploitation can make them of better promise than they hold forth now; the next thing is actual colliery work, which will of course very much depend on the demand which may arise either out of the completion of the short line of hill tramway on the slopes of the range south of Cherra Poonjee, or through utilization of the fuel on the upland to the eastward. The report on the Cherra Poonjee field appeared in the Records for August, and that on Lakadong appears in the present number.

At the close of the year, Mr. LaTouche, having so far completed coal enquiry in Assam, was attached to the Lushai column of the Chin-Lushai expedition, and is at present extending our knowledge of the little-known tracts of the Lushai Hills.

Messrs. T. W. H. Hughes, T. D. La Touche, and Dr. Noetling.

Tin.

BURMA.—The exploitation of tin in Tennasserim continues in the hands of Mr. Hughes; and towards the end of the year it was put in active operation by the employment of a professional staff of European exploiters and Chinese miners obtained from the Straits Settlements. The conditions of tin-mining in the Mergui District are fully set forth in his paper in the Records for August last; and barring delays or obstructions which are certainly not unlikely in such an out-of-the-way and unopened dense jungly tract as that between Mergui and Maliwun is, a fair preliminary practical development of what certainly appear to be very favourable mineral conditions of the country may be expected within the next twelve months. I have the fullest confidence in Mr. Hughes' ability and desire to further by this exploitation the very liberal and wise effort being now made by the Government of Burma to encourage public enterprise in the development of its mineral resources.

Coal and oil. Upper Burma.

In Upper Burma, much has been done by Dr. Noetling in the rather rapid explorations which he had to make in regions known more or less favourably for coal oil, iron, and precious stones; and while so engaged he was also employed in framing suggestions for the Government for a code of mineral concessions and leases. His most important work was at the oil-fields of what he has designated, though for no very cogent reasons, as Twingong and Beme, but which have long been known as those of Yenangyoung; and in the Chindwin coal-field. His report on the oil-fields published in the Records for May is very complete and elaborate in details, while the calculations based on these as to the past and future of the oil production form quite a new and interesting feature in geological description of oil regions. He has also prepared a very long and detailed description of the Chindwin coal-field, which will appear in a future number of the Records.

Dr. Noetling returned to Calcutta in the rains, but has again been despatched to Burma to meet the very urgent demand for exploitation in that country. Palæontological research at the collections stored in the Museum at head-quarters is therefore deferred until opportunity for his return occurs; while the Survey must depend now more than ever on such gracious assistance as can be given by *savants* at home or on the Continent who have hitherto, or who may now take up, the study of any special fossil series. In this connection, we have to acknowledge the generous labours of Mr. Lydekker, Dr. P. Martin Duncan (who has just sent in a description of the *Syringosphæridæ* from the Karakorum), and Dr. Waagen; as also the offers of Dr. Feistmantel and Mr. Theobald to take up other work of a special kind. It is to be hoped, too, that arrangements may be made for inducing such distinguished specialists as Professors Neumayr, Mojsisovics, and Toula to engage in the study and description of our large collection of fossils, now many years in store, from the sedimentary rocks of the Central Himalayas, the geological memoir on which is now all but completed by Mr. Griesbach.

Deputation with H. H. the Ameer of Afghanistan.—Mr. Griesbach returned to India last July. His work with the Ameer was, as is now so very largely the case in the Survey, geologico-industrial; though this was greatly retarded by unforeseen political complication in the State. During his journey in 1888, up the Logar Valley to the Khurd Kábul Valley, Upper Wardak, Cherkh, Kharwár, Zanakhán, Ghazni, &c., the most interesting geological work was the recognition of at least three horizons: the Rhætic with *Lithodendron* (in Kharwár), the Upper Jurassic (or possibly neocomian) plant-beds near the Shutargárdan, and, finally, well-developed nummulitics (in Kharwár and Shilghar). He examined the copper lodes of the Logar and Khurd Kábul areas, the magnesite of the Logar and the entrance to the Tangi Wardak, the graphite of Cherkh, the iron and lead ores of Kharwár, and the argentiferous lead ore of Zanakhán near Ghazni. It turns out also that the entire Upper Surkh-ab Valley from near Doáb-i-Mékhzari to near Dahana Iskar is practically one big coal-field with numerous thick seams of good coal of Triassic and Rhætic age.

Survey Publications.—Dr. Waagen's further contribution on the Salt Range Fossils, in Part I, Vol. IV, Geological Results, was issued at the close of the year. The current volume (XXII) of the Records contains twenty-five papers, fourteen of these being on industrial or economic questions; and as of old, the Survey has to acknowledge outside contributions from Mr. Lydekker and Drs. Waagen and Warth.

Library.—1,584 volumes, or parts of volumes, were added during the year: 1,093 by presentation or exchange, and 491 by purchase.

Museum and Laboratory.—I regret to write that our work in each of these sections of the Department has been most seriously and even sadly hampered by the retirement of Mr. Mallet in June last, and by the death of Mr. Jones, who succeeded him in these very important charges. Mr. Mallet retired through failing health after a long and most successful career in the Survey, a good deal of the latter part of his service having been spent in laboratory research, not only of great economic, but of eminent scientific value. So wrapt, indeed, is he still in the interests of our research that he left with a distinct understanding that he would yet work for love of the service he so regretted to leave; and my hopes are that the department will benefit considerably by his advice on questions which may require further authoritative examination than can be carried out in our laboratory. Mr. Jones, though scarcely endowed with the clear acumen of his senior, was, by his steadiness of enquiry and his great reliability, in a fair way of successfully filling the place of his retired colleague; and the department finds it very difficult to repair the loss sustained in his death in October last.

In the meantime and until the post is filled by a more specially trained chemist and mineralogist, Mr. Lake, who had to be recalled from Baluchistan through ill health, conducts the work of the Museum and Laboratory.

The number of assays and reports on metalliferous minerals for mercantile firms, mining companies, and private individuals has increased considerably during the year; and, as already stated, both Mr. Mallet and Mr. Jones were despatched for special enquiries for the Governments of India, Bengal, and the Central Provinces, connected with coal, iron, pottery, and gas industries.

WILL .KING,
Director, Geological Survey of India.

CALCUTTA:
January 31st, 1890.

List of Societies and other Institutions from which Publications have been received in donation or exchange for the Library of the Geological Survey of India, during the year 1889.

Adelaide.—Royal Society of South Australia.
Albany.—Museum of Natural History.
„ New York State Museum.
Ballarat.—School of Mines.
Baltimore.—Johns Hopkins University.
Batavia.—Batavian Society of Arts and Sciences.
„ Koninklijke Natuurkundige Vereeniging in Nederlandsch-Indië.
Belfast.—Natural History and Philosophical Society.
Berlin.—German Geological Society.
„ International Geological Congress.
„ Königlich Preussische Geologische Landesanstalt und Bergakademie.
„ Royal Prussian Academy of Science.
Bologna.—Royal Academy of Sciences.
Bombay.—Bombay Branch, Royal Asiatic Society.
„ Marine Survey of India.
„ Meteorological Department.
„ Natural History Society.
Bordeaux.—Linnean Society of Bordeaux.
Boston.—American Academy of Arts and Sciences.
„ Society of Natural History.
Breslau.—Silesian Society.
Brisbane.—Queensland Branch, Royal Geographical Society of Australasia.
„ Royal Society, Queensland.
Bristol.—Bristol Naturalists' Society.
Brussels.—Royal Academy of Science.
„ Royal Geographical Society of Belgium.
„ Royal Malacological Society of Belgium.
Bucarest.—Bureau Géologique, Roumain.
Budapest.—Hungarian National Museum.
„ Royal Hungarian Geological Institute.
Buenos Aires.—National Academy of Sciences, Cordoba.
Calcutta.—Agricultural and Horticultural Society.
„ Archæological Survey.
„ Asiatic Society of Bengal.
„ Editor, "Indian Engineer."
„ Editor, "Indian Engineering."
„ Indian Museum.
„ Meteorological Department, Government of India.

Calcutta.—Survey of India.
Cambridge.—Philosophical Society.
Cambridge, Mass.—Museum of Comparative Zoölogy.
Cincinnati.—Society of Natural History.
Copenhagen.—Royal Danish Academy.
Dijon.—Academy of Sciences.
Dresden.—Isis Society.
Dublin.—Royal Dublin Society.
„ Royal Irish Academy.
Edinburgh.—Geological Society.
„ Royal Scottish Society of Arts.
„ Royal Society.
„ Scottish Geographical Society.
Glasgow.—Geological Society.
„ Glasgow University.
„ Philosophical Society.
Gotha.—Editor, Petermann's Geographische Mittheilungen.
Göttingen.—Royal Society.
Halle.—Kais. Leopoldinisch-Carolinische Deutsche Akademie der Naturforscher.
„ Natural History Society.
Harrisburg.—Second Geological Survey of Pennsylvania.
Hobart.—Royal Society of Tasmania.
Königsberg.—Physikalisch-Ökonomische Gesellschaft.
Lausanne.—Vaudois Society of Natural Sciences.
Leiden.—École Polytechnique de Delft.
„ Geological Museum.
Liége.—Geological Society of Belgium.
Leipzig.—Geographical Society.
Lille.—Société Géologique du Nord.
Lisbon.—Geological Commission of Portugal.
Liverpool.—Geological Survey.
London.—Geological Society.
„ Iron and Steel Institute.
„ Linnean Society of London.
„ Royal Asiatic Society of Great Britain and Ireland.
„ Royal Geographical Society.
„ Royal Institute of Great Britain.
„ Royal Society.
„ Society of Arts.
„ Zoological Society.
Madras.—Government Astronomer.
Madrid.—Geographical Society.
„ Royal Academy of Sciences.
Manchester.—Geological Society.
„ Literary and Philosophical Society.

MELBOURNE.—Department of Mines and Water Supply, Victoria.
,, Public Library, Museums, and National Gallery, Victoria.
,, Royal Society of Victoria.
MILAN.—Society of Natural Science.
MONTREAL.—Geological and Natural History Survey of Canada.
,, Royal Society of Canada.
MOSCOW.—Imperial Society of Naturalists.
MUNICH.—Royal Bavarian Academy.
NAPLES.—Royal Academy of Science.
NEUCHATEL.—Society of Natural Sciences.
NEWCASTLE-ON-TYNE.—North of England Institute of Mining and Mechanical Engineers.
NEW HAVEN.—The Editors of the "American Journal of Science."
NEW YORK.—Academy of Sciences.
PARIS.—Geographical Society.
,, Geological Society of France.
,, Mining Department.
,, The Editor of the "Annuaire Géologique Universel Revu de Géologie et Paléontologie."
PHILADELPHIA.—Academy of Natural Sciences.
,, American Philosophical Society.
,, Franklin Institute.
PISA.—Society of Natural Sciences, Tuscany.
ROME.—Geological Survey of Italy.
,, Royal Academy.
,, Royal Geological Commission of Italy.
SACRAMENTO.—California State Mining Bureau.
SAINT PETERSBURG.—Geological Commission of the Russian Empire.
,, Imperial Academy of Sciences.
SALEM.—Essex Institute.
SHANGHAI.—China Branch, Royal Asiatic Society.
SINGAPORE.—Straits Branch, Royal Asiatic Society.
SYDNEY.—Australian Museum.
,, Department of Mines, New South Wales.
,, Linnean Society of New South Wales.
,, Royal Society of New South Wales.
TOKIO.—Seismological Society of Japan.
TORONTO.—Canadian Institute.
TURIN.—Royal Academy of Sciences.
VENICE.—Royal Institute of Science.
VIENNA.—Imperial Geological Institute.
,, Imperial Natural History Museum.
,, Royal Academy of Science.
WASHINGTON.—National Academy of Sciences.
,, Smithsonian Institution.
,, United States Geological Survey.

WASHINGTON.—United States Mint.
WELLINGTON.—Colonial Museum and Geological Survey of New Zealand.
„ Department of Mines, New Zealand.
„ New Zealand Institute.
YOKOHAMA.—German Naturalists' Society.
YORK.—Yorkshire Philosophical Society.
The Secretary of State for India.
The Governments of Bengal, Bombay, India, Madras, and Punjab.
The Chief Commissioners of Assam, Burma, and Central Provinces.
The Resident at Hyderabad.

Report *on the* Lakadong Coal-field, Jaintia Hills; *by* TOM D. LATOUCHE, B.A., *Deputy Superintendent, Geological Survey of India.* (With 2 plans.)

The coal-field of Lakadong is situated near the southern edge of the Jaintia Hills, about 7 miles from the plains at Burghat on the Harri river, and at an elevation of about 2,200 feet above them. The coal occurs near the top of several small plateaus, the lower portion of which is formed of thick beds of nummulitic limestone, as at Cherra Punji, rising to about 200 feet above the general level of the hills; these detached plateaus, are evidently the remnants of beds of limsetone and coal-bearing rocks, which at some former time extended far beyond their prseent limits, the intervening portions having been removed by denudation since the upheaval of the hills: their surface slopes gently towards the South or South-East, and is generally even, except where a low ridge, formed of an upper band of thick-bedded limestone, rises near their centre. In all these plateaus, coal is found cropping out at various points on the precipitous scarps by which they are surrounded, and at a very short distance below the top, generally from 10 to 20 feet; this makes it an easy matter to get the coal, either by driving in galleries from the outcrop, or by digging shallow pits on the surface of the plateau.

An account of the field, with a small-scale plan of one of the plateaus, was published by Dr. Oldham in vol. i, Part 2, of the Memoirs, Geological Survey, p. 145: he gives a description of the various outcrops visible at the time of his visit in 1852, which appear to be in much the same condition now as they were then, since very little coal has been extracted in the interval, and estimated the total quantity of coal at 1,500,000 tons; but he appears to have taken into account only the largest of the plateaus, called Umlotodo, on which the village of Lakadong stands; the other plateaus, however, contain an insignificant amount of coal as compared with this.

The present notice is the result of a survey made during a recent visit to the field, about which inquiries have lately been made by certain Calcutta firms with a view to its development. Owing to want of time, I was unable to do more than survey two of the plateaus, those of Umlotodo and Umat, which are practically portions of the same, but are divided from each other by a narrow and deep ravine. The others, lying as they do a greater distance from the plains, and containing, as is shown in a report by the late Mr. Ringwood, no very large amount of coal, can very well remain until some progress has been made with the opening out of the two now described; but it will probably be found, judging from Mr. Ringwood's report, that the seams in them are too thin to be profitably worked.

THE UMLOTODO PLATEAU.

In this portion of the field coal is actually visible in twelve places, in most of which it has been worked by the natives to a small extent at one time or another, but no doubt many other outcrops would be found if the jungle that covers all the hill-sides below the top of the plateau were cleared away. In many places also, where the face of the hill-side is accessible, no coal is visible because, being a softer rock than the sandstone above, it has been washed out and the sandstone has settled down, thus concealing the outcrop. The visible outcrops, taken in order as marked on the accompanying plan, are as follow:—

(1) The seam is exposed near the bottom of a funnel-shaped hollow, caused by underground denudation of the limestone beneath; it occurs at about 15 feet from the surface and is 6 feet 4 inches thick; the coal is bright and of good quality, but, like all the coal in this field, is traversed by numerous small joints, which cause it to split into small cuboidal fragments. The seam dips to the south-east at about 8°, but this and other instances in which the rocks dip at a greater angle than the normal dip of the whole field, which is very slight, is probably due to the disturbance of the rocks caused by their falling in, and does not extend to any distance from the edges of the hollow. When Dr. Oldham visited the place, this was the most extensive working in the field, and five headings had been carried in to a distance of 9 fathoms, but these have now fallen in, except one which is 20 feet deep, and have been abandoned for many years. Overlying the coal in this and all the other places where it is seen is a thick bed of sandstone, of a sharp gritty texture, which is fairly hard when first opened out, and forms an excellent roof to the workings, but on exposure to the air it becomes soft, and would require propping up, if required to stand for any time.

(2) The seam here is exposed at the edge of the plateau, at about 12 feet below the surface, and is 3 feet thick.

(3) At the edge of the plateau the coal lies at about 10 feet below the surface and is 2 feet thick.

(4) Some coal has been extracted from two small pits not far from the edge of the plateau, about 10 feet deep; the seam appears to be about 2 feet thick, but is not well exposed.

(5) At edge of plateau; the coal is 3 feet thick and only 7 feet below the surface.

(6) Here a funnel-shaped hollow has been formed on the side of a small knoll, and the coal is found at the entrance to a cave formed by the falling in of the underlying limestone. The coal is 2 feet 6 inches in thickness, but dies out to nothing within a distance of about 12 feet; it appears again a few feet further on, where it is only 1 foot thick. This thinning out of the coal is noticeable in most of the sections seen; it may be due either to denudation of the coal before the sandstones overlying it were laid down, or it may be merely caused by the settling down of the harder sandstones above upon the coal where the edges of the beds have been exposed. I think, however, that, considering the very variable thickness of the seam in the different sections, the former is more likely to be the correct supposition, and that the coal only occurs in lenticular beds: this, of course, detracts enormously from the value of the field and renders it extremely difficult to form a reliable estimate of the amount of coal contained in it.

(7) Here also the coal is exposed at the entrance to a large cave formed in the same manner as the preceding; there are two seams, divided by about

18 inches, of carbonaceous shale; the upper is 1 foot thick and the lower 4 feet, but they quickly thin out horizontally and disappear altogether.

(8) Here the coal is only 1 feet 10 inches thick, but is more constant in thickness than at other places, at least as far as it can be traced, a distance of about 20 feet.

(9) The seam occurs at about 12 feet from the surface, but is not well exposed, as the rocks above have fallen in upon it. It is said to have been about 3 feet thick.

(10) The coal is exposed here in a narrow ravine at about 30 feet below the surface of the plateau; its thickness is about 2 feet 6 inches where thickest, but it thins out to only 1 foot in about 12 or 15 yards.

(11) This is the thickest outcrop seen in the whole field; it occurs at the head of a narrow ravine, or croom, and at the time of Dr. Oldham's visit was being worked. The seam is divided horizontally by a band of hard shaly sandstone, about 3 feet thick; the upper part, when Dr. Oldham saw it, was about 5 feet thick, and the lower in one place at least 8 feet, but when I saw it the two seams only measured 4 feet and 5 feet 6 inches, respectively. A large part of the old working is now covered by debris, so that I probably saw a different part of the seam, which, according to Dr. Oldham, dwindles from 8 to 4 feet within a short space. About 10 feet of sandstone separate the upper seam from the surface of the plateau.

(12) A small pit has been opened here, and is the only one now being worked, 200 maunds having lately been taken out for a tea plantation at the foot of the hills. The top of the seam, which is 2 feet 6 inches thick, is only 6 feet from the surface: a small heading has been driven into the coal to a depth of 2 feet.

It will be seen from the foregoing that the thickness of the seam in different parts of the plateau is very variable, and that it is by no means certain that coal would be found at every point, as it appears to lie in lenticular beds or pockets of limited extent. For this reason it would be advisable, before any expense is incurred in improving the communications with the plains, and in obtaining machinery, &c., for working the coal, to test the thickness of the seam by making a series of small pits or borings. These might be made in any direction across the field, and would cost very little, as the average depth would not be more than 15 feet or so, and local labour might be employed. They could also be used afterwards for extracting the coal, if it was found that the field was worth working.

The area of the Umlotodo plateau is about 11,523,000 square feet, which, estimating the average thickness of the coal at 2 feet, would give a total quantity of 853,000 tons of coal. The estimate of the thickness of the seam is of course open to correction, and it should be said that in 1852 Dr. Oldham gave 3 feet as the probable average thickness, which would imply a total quantity of coal of 1,280,000 tons. It is impossible to say, until the thickness is further tested by pits or borings, which of these estimates is more nearly correct; Dr. Oldham gives 1,500,000 tons as the probable total quantity of coal, but he over-estimated the area of the field, which he put down at half a square mile, by nearly 2½ millions of square feet.

THE UMAT PLATEAU.

In this portion of the field a good section of the coal is seen at only one point; this is marked (13) on the plan; the seam occurs at about 25 feet below the surface, and is 4 feet thick; it is exposed for abouf 20 feet horizontally, beyond which it is covered by debris and jungle.

Coal has also been slightly worked at the points marked (14) and (15) on the plan, but the rocks above have settled down at each of these places, and no coal is now visible.

The area of this plateau is 4,202,000 square feet, and if the average thickness of the coal is put down at 2 feet, it would yield a total quantity of 311,000 tons of coal. This, added to that in the Umlotodo plateau, gives a total of 1,164,000 tons for the portion of the field surveyed.

The extraction of the coal in this field will be a simple matter, seeing that it lies so close to the surface; the best method of mining it would be, I think, to sink shallow pits at short distances from each other, and on reaching the coal, drive headings from one to the other along the seam. The coal included in the area between these headings might then be entirely worked out, and the roof allowed to fall in. Some propping of the roof will be necessary while the coal is being secured, but this will not have to be very elaborate, as the sandstone forming the roof should stand very well, and wood suitable for this purpose is abundant in the vicinity. As at Cherra, the mines could be so arranged as to be drained naturally through adits opening on the face of the cliffs surrounding the plateau, and no pumping machinery would be required. A good road would have to be made down to the plains at Burghat, but this would not present any great engineering difficulty, as no large rivers have to be crossed, and the distance is only 7 miles, while the elevation of the field above the plains is about 2,200 feet, or about half that of the coal-field at Cherra Punji. From Burghat the coal can be taken in boats to any part of Cachar or Sylhet.

I am not aware that any analysis has been made of this coal, but from its appearance I should say that it is very similar to the coal of Cherra; and it belongs to the same period,—the Nummulitic or Lower Eocene division of the Tertiary formation.

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On the Pectoral and Pelvic Girdles and Skull of the Indian Dicynodonts. By R. LYDEKKER, B.A.

In describing certain fragmentary bones from the Panchet beds, which appeared to be referable to the pectoral girdle of the Indian Dieynodonts, Professor Huxley[1] experienced considerable difficulty in deciding as to their true position in the skeleton, and also in correlating them with the homologous bones of the African representatives of the same group. In the memoir cited, the Professor described two kinds of bones which he considered to belong to the pectoral girdle. One bone (vol. v, figs. 1-3) was of an expanded and flattened type, and was considered to be probably

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[1] Pal. Ind., ser. 4, vol. i, pt. i.

a coracoid, although it was suggested that it might possibly be a scapula. The other bone (vol. v, figs. 4-5), which was of a more elongated type, appeared to be decidedly a scapula, and the Professor would have regarded it as the scapula of the Indian Dicynodont had it not been for certain bones from South Africa referred by Sir R. Owen to that portion of the skeleton. In a memoir subsequently published by the present writer[1] it was concluded that the elongated bones were in all probability the scapulæ of Dicynodonts, while the flattened bones were regarded as the coracoids. A smaller coracoid-like bone has, however, been figured (l. c., pt. iii, pl. ii, fig. 8), which, it was suggested, might perhaps belong to the small Dinosaur to which Professor Huxley applied the name *Ancistrodon*, since, if the flattened bones figured by the latter writer were really the coracoids of Dicynodonts, it was quite evident that the smaller bone must belong to a totally different form.

The whole difficulty really arose from the above-mentioned African bones figured by Sir R. Owen in the Trans. Geol. Society, ser. 2, vol. vii, pl. xxiv, which were regarded as belonging to the pectoral girdle, but, as is shown by associated specimens in the British Museum, are in reality referable to the pelvic girdle. Thus, the large and expanded bone represented in fig. 2 of the plate cited, which was considered to be either a scapula or a coracoid, and is evidently homologous with the expanded Indian specimens figured by Professor Huxley, proves to be the ilium; while the smaller and perforated bone in the lower part of the same figure turns out to be the imperfect pubis and ischium.

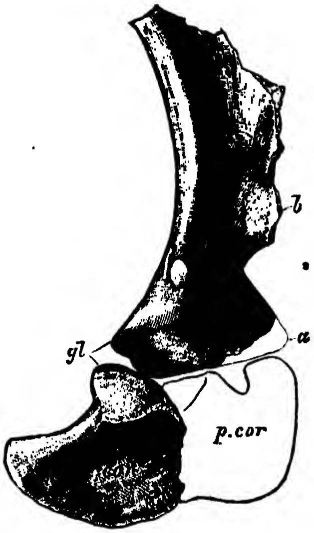

FIG. 1.—Dorsal aspect of the cartilage bones of the right side of the pectoral girdle of *Ptychosiagum orientale*. ¼, *sc.* = scapula:
a. Acromial process of d°.;
b. Supra-acromial process of d°.;
cor. = coracoid; *p. cor.* = precoracoid: *gl.* = glenoid cavity.

Thus, we find that the expanded Indian bones figured in plate v, figs. 1-3, of Professor Huxley's memoir, have nothing to do with the pectoral girdle; and we are consequently free to regard both the elongated bones represented in figs. 4, 5 of that plate, and the coracoid provisionally referred to *Ancistrodon* as really belonging to the pectoral girdle of the Indian Dicynodonts. A specimen of the imperfect right side of the pectoral girdle of a comparatively small African Dicynodont preserved in the British Museum, (No. 36287), and figured in "the Philosophical Transactions" for 1888, p. 492, fig. 1, at once shows the mutual relations of the two Indian bones, which are placed in their natural relative positions in the accompanying wood-cut. The scapula corresponds exactly with that portion of the scapula remaining in the African specimen, and also with the larger entire African scapula described by Sir R. Owen as *Platy-*

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[1] Pal. Ind., ser. 4, vol. i, pt. iii, pp. 7-9.

podosaurus, which likewise belongs to a Dicynodont. The British Museum specimen No. 36287 shows that the ventral portion of the pectoral girdle was formed by a coracoid and pre-coracoid, both of which enter into the composition of the glenoid cavity. Now, the small Indian coracoid figured as *Ancistrodon* agrees precisely wtth the coracoid of the African specimen, and shows on its anterior border a distinct articular surface for the pre-coracoid, of which the outline is introduced into the wood-cut. Another specimen in the British Museum shows that the distinctness of the pre-coracoid from the coracoid was a character found in adult specimens of the largest Dicynodonts, as well as in examples that may belong to immature individuals. It may be observed in passing that it has been shown by the writer in the memoir cited that the common Indian Dicynodont is referable to that genus commonly known as *Ptychognathus ;* since, however, the latter term is preoccupied, the name *Ptychosiagum* has been proposed by the writer [1] in lieu thereof. There has been some confusion in regard to the processes marked *a* and *b* in the figure of the scapula, which has been discussed in a paper recently read by the writer before the Zoological Society. With regard to the bones of the pelvis, the ilium figured by Professor Huxley in plate v, fig. 1 of the memoir cited, is represented in a reversed position in fig. 2, with the missing portion of its posterior border and the outline of the ischium and pubis restored from specimens in the British Museum (Nos. R. 1698 and 1699), which show the three bones in association. We thus see that the imperfect bone represented in the Pal. Ind., ser. 4, vol. i, pt. iii, where the suggestion is made that it may be a portion of the pubis, does not belong to the cartilage bones of either the pectoral or pelvic girdle. I am, however, at present unable to refer this bone to its true position in the skeleton.

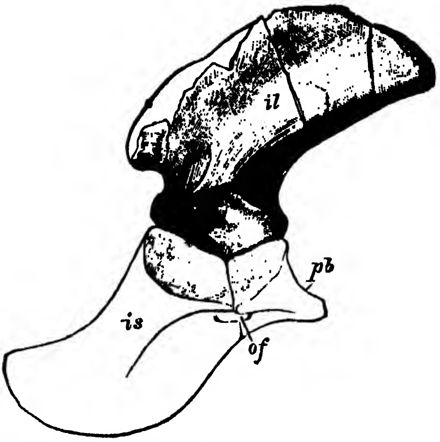

FIG. 2.—Reversed view of the left side of the pelvis of *Ptychosiagum orientale ;* the pubis and ischium being restored from specimens in the British Museum. ⅔, *il* = ilium ; *Is.* = ischium ; *pb.* = pubis ; *o. f.* = obturator foramen.

This revised determination of the bones of the pectoral and pelvic girdles of the Indian Dicynodonts shows that they correspond in every respect with the homologous elements of the skeleton of their South African allies.

Devoting a few words to the consideration of the fragments of the skull of the Indian form, attention may first be directed to the imperfect left side of the occipital region represented in fig. 3, with a restored outline of the entire occiput from the African *Ptychosiagum declive.* The Indian fossil has been already figured by myself

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[1] Nicholson and Lydekker; Manual of Palæontology, 3rd ed., vol. ii, p. 1063 (1889).

in Pal. Ind., ser. 4, vol. i, pt. 3, pl. i, fig. 2; but in making the restoration of the opposite side the fragment was placed too nearly vertically. In the present figure this has been corrected; and the resemblance between the occiput as thus restored and that of the African form is so close as to render it difficult to discover even specific distinctions. The Indian specimen indicates an individual nearly of the size of *P. declive* but is specifically distinguished by the greater width of the interparietal. In the former figure the bones were lettered according to Sir R. Owen's determination, but a revised nomenclature is now adopted.

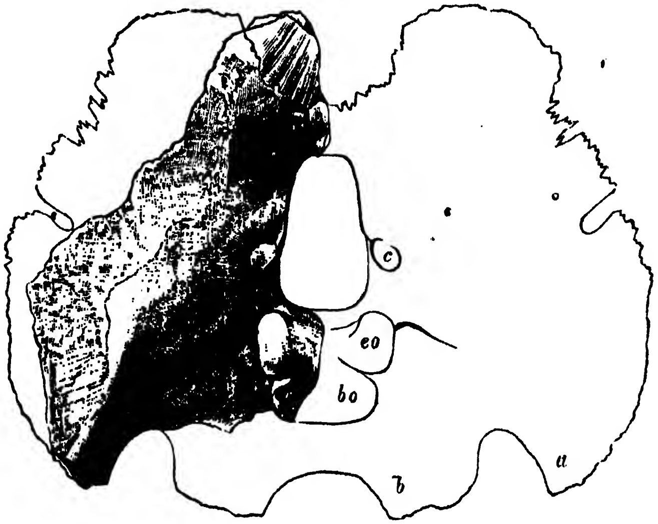

FIG. 3.—Part of the left side of the occiput of *Ptychosiagum orientale*, with a restored outline of the whole occiput from *P. declive*. Nat. size. *bo.* = basioccipital; *eo.* = exoccipital; *c.* = tubercle on supra-occipital; *a.b.*—inferior processes. The bone above the supra-occipital is the interparietal.

It may be added that the undetermined bone represented in pl. ii, figs. 12, 13, of the menoir last cited, proves to be the articular bone of one ramus of the mandible.

Finally, I should observe that I have provisionally included all the above-mentioned specimens under one specific heading, since, beyond variations in point of size, I do not find any distinctive differences in homologous bones.

Note on certain Vertebrate Remains *from the* Nagpur District; *by* R. LYDEKKER, B.A. (*With description of a Fish-skull, by* A. SMITH WOODWARD, F. G. S.)

Having recently examined the Vertebrate remains from the Nagpur district in the Museum of the Geological Society, I have observed among them three specimens which are of considerable interest. Two of these belong to reptiles, while the third is a portion of the skull of a fish. In regard to the latter, my friend Mr. A. Smith Woodward, F G.S., of the British Museum, has been good enough to record the results of a careful examination which he has made with a view to determining its affinities. The fish-skull and the Chelonian plastron were presented by the late

Reverend S. Hislop, of Nagpur, while the third specimen, which is a reptilian tooth is the gift of a Dr. Rawes. My thanks are due to the President of the Society for permission to describe these specimens.

I.—DINOSAURIAN TOOTH FROM TAKLI.

Many years ago Dr. Rawes presented to the Museum of the Geological Society the crown of a compressed and serrated reptilian tooth, which he had obtained at Takli close to Nagpur.[1] Mention is made of this tooth by Mr. Hislop in the "Journal of the Bombay Branch of the Royal Asiatic Society," vol. vi, p. 196 (1861), and also in the "Quarterly Journal, Geologicial Society," vol. xx, p. 281 (1864). In the former passage, the specimen is stated to have been obtained from the Intertrappeans; while in the latter, it is compared to the teeth of *Megalosaurus*, and stated to resemble other teeth obtained by Mr. Hislop from the Maleri beds, although of a thinner and more compressed type. Mention is again made of this specimen (which I had not then seen) by myself in the Pal. Ind., Ser. iv, vol. i, pt. 3, p. 26, when I considered that it was probably referable to *Megalosaurus*, and suggested that both this and the Maleri teeth really came from the Lametas. The subsequent finding of teeth in the Maleri beds, which I now know to be of the same general type, and of which examples are figured in the Pal. Ind., *op. cit.*, pt. 5, p. 29, fig. 1, and pl. vi, fig. 10, shows that Mr. Hislop's specimens were really of Maleri age.

With regard to the age of Dr. Rawes' specimen, it would appear improbable that a Dinosaur should exist at the period of the Eocene Intertrappean beds, and since, according to Mr. Blanford,[2] Infratrappean Lameta beds do occur at Takli beneath the Intertrappeans, while the fossil is evidently one found lying on the surface of the ground,[3] it appears highly probable that it is really of cretaceous (Lameta) age.

This interesting specimen is figured of the natural size in the accompanying woodcut (fig. 1). In its highly compressed crown, with serrated edges, this tooth presents a marked general resemblance to small specimens of the teeth of *Megalosaurus*. A closer examination shows, however, that the crown is proportionately shorter; while its posterior border, instead of presenting the marked

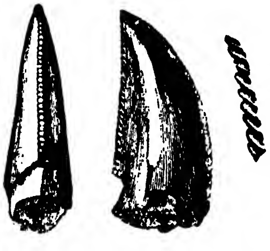

FIG. 1.— Posterior and lateral aspects of the crown of a tooth of *Massospondylus rawesi* from the Lameta (?) beds of Takli, near Nagpur $\frac{1}{1}$. Part of the serration of the posterior border is shewn on an enlarged scale.

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[1] See Blanford; Mem. Geol. Surv. Ind., vol. ix, p 25.

[2] *Op cit.* p. 23.

[3] The mixture of Infra and Intertrappean fossils in several locations is noticed in the "Manual of the Geology of India," p. 311.

concavity found in the Megalosaurian teeth, is nearly straight; and the serrations are comparatively long and slender, and directed obliquely to the axis of the tooth, instead of being short and blunt, and directed at right angles to this axis, as in the latter. Again, the serrations occupy the whole length of the anterior border of the crown, whereas in *Megalosaurus* they do not occur on the lower part of this border. In all the above points this tooth closely resembles the Dinosaurian teeth from Maleri, although distinguished by its greater lateral compression. Moreover, these features are repeated in the teeth of the English Triassic genus *Thecodontosaurus*, in which, however, the posterior border of the crown in slightly convex. Now, *Thecodontosaurus* belongs to that generalized family of Theropodous Dinosaurs for which the name *Anchisauridæ* has been proposed, and I have already given reasons for regarding the Maleri Dinosaur[1] as belonging to that family, as a representative of the African genus *Massospondylus*. The more compressed crown of the Takli tooth does not of itself necessarily imply its generic distinction from the Maleri form, and I accordingly propose to refer it provisionally to that same genus, under the name of *Massospondylus rawesi*. Since, moreover, the Maleri form has not yet received a name, I propose that it should be known as *M. hislopi*; the type specimen being the vertebra figured in the Pal. Ind., ser. 4, vol. i, pt. 5, pl. v, fig. 4.

If I am right in regarding *Massospondylus* as referable to the *Anchisauridæ*, the Takli tooth is of very considerable interest, as indicating the survival of that family (or at all events of a closely allied one) to the period of the middle Cretaceous: the American and English types being characteristic of the Upper Trias.

II.—PART OF A CHELONIAN PLASTRON FROM PHISDURA.

Among the remains collected by Mr. Hislop at Phisdura near Nagpur, mention is made by him in the "Journal of the Bombay Branch of the Royal Asiatic Society," vol. vi, p. 196, of the greater part of the shell of a small Chelonian, and also "part of a very thick plastron of another species of the Chelonian order." Among the specimens presented by Mr. Hislop to the Geological Society, there is part of the anterior extremity of a plastron which answers to the above brief description, and is therefore probably the specimen referred to. Mr. Hislop considered that these remains were derived from the Infratrappean Lametas. Since, however, *Physa prinsepi*, of the Bombay Intertrappeans, is common at Phisdura, there is a strong probability (as mentioned on p. 311 of the "Manual of the Geology of India") that concealed Intertrappean beds occur at this place; and since the Chelonian specimen under consideration belongs to a genus occurring in the Bombay Intertrappeans, there is a strong presumption that it is likewise of Eocene age.

Before proceeding further it should be observed that the Chelonian from the Intertrappeans of Bombay was originally described by Dr. Carter in the "Journal, Bombay Branch, Royal Asiatic Society," vol. iv, p. 186 (1852), under the name of *Testudo leithi*, but was subsequently referred by Dr. Gray in the Ann. Mag. Nat. Hist., sec. 4, vol. viii, p. 339, to the genus *Hydraspis*, which is now confined to South America. The type specimen, which is probably in the museum of the Bombay Asiatic Society, indicates an individual considerably inferior in size to adult examples of the existing *H. hilarii*.

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[1] Records, G. S. of I., vol. xxi, p. 146.

In the accompanying woodcut (fig. 2) Mr. Hislop's specimen is figured on a reduced scale side by side with the anterior extremity of the plastron of *Hydraspis hilarii.* The fossil consists of the anterior portion of the right epiplastral; and a comparison of the two figures reveals such a close correspondence between the two as to indicate their generic identity. The right half of the area occupied by the large intergular shield so characteristic of the Pleurodiran section to which *Hydraspis* belongs is well shown, and agrees closely in contour with that of the figured adult example of the living species, which is of somewhat smaller size.

Compared with Dr. Carter's figure of the type of *H. leithi,* the present specimen differs not only by its much larger dimensions, but also by the proportionately larger size of the gular and the smaller size of the intergular shields. The difference in points of size is obviously of no importance, and since nearly similar degrees of variation occur in the proportions of the gular and intergular shields in the existing forms, it is probable that the Phisdura specimen should be referred to *Hydraspis leithi.* The present specimen is of interest, as extending the range of that species into the Central Provinces; and also as lending support to the evidence afforded by *Physa Prinsepi* that Intertrappean beds occur at Phisdura.

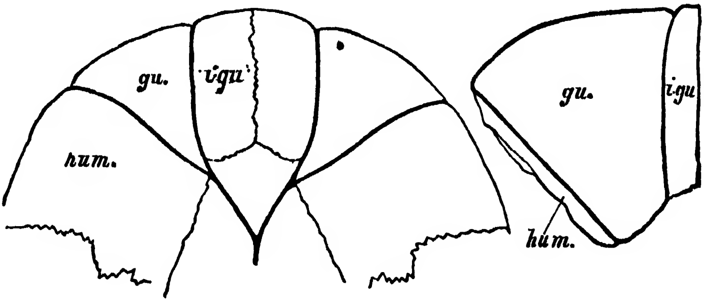

FIG. 2.—Anterior extremity of the plastron of *Hydraspis hilarii,* and part of the right epiplastral of *H. leithi.* ½ nat. size; *gu.*-gular shield; *i. gu.*-intergular do.; *hum.*-humeral do.

3. FISH-SKULL FROM DONGARGAON.

The fish-skull was obtained from the Infratrappean Lameta beds at Dongargaon (Dongargaum), 6 miles east by south of Warora,[1] and is mentioned in the Quart. Journ., Geol. Soc., vol. xvi, pp. 162-163 (1860). In that passage it is stated that the specimen had been submitted to the late Sir Philip Egerton, who considered that it probably indicated a fish allied to the genus *Sphyrænodus* of the London clay. The specimen is unfortunately but very imperfectly preserved, so that its exact determination is no easy matter. Mr. Smith Woodward's note upon it is as follows:—

" The fossil exhibits the greater portion of the skull of a long-mouthed fish, and so far as preserved, measures 0·240 m. in length. The cranial roof is seen from the upper aspect nearly complete, although much crushed posteriorly, and evidently wanting a short length in front. It is very narrow and slender, a pair of elongated bones, which are broad behind and tapering anteriorly, extend from the occiput far

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[1] See " Manual of the Geology of India," p. 311.

towards the anterior extremity of the snout; and the lateral notch for the orbit on either side occurs at a point about one third of the total length of these bones from their hinder end. Another pair of elongated, but smaller, bones occurs further forwards; their slender backwardly-tapering extremities being intercalated for a considerable space between the anterior ends of the hinder bones. A fragment of the maxilla remains on the right side, exhibiting several teeth; and both rami of the mandible are seen displaced from beneath the cranium in a shattered condition. The latter are long and slender, not excessively deepened behind, and the ramus of the right side retains traces of the teeth. In the anterior region of both the upper and lower jaws the teeth are conical and marked with strong vertical wrinkles, and tipped by a small cap of enamel. There is an outer series of small approximated, and uniform teeth, internally to which we find a row of larger teeth, separated from one another by considerable intervals. In the hinder portion of the mandible the teeth become very short and stout, but since no oral view is obtainable of the splenial element, it is impossible to determine whether they form a triturating pavement. None of the bones are sculptured externally.

" Although originally compared with *Sphyrænodus* (—i.e., *Dictyodus*) by Sir Philip Egerton, the fossil does not appear to present much resemblance to the head of a Scomberoid Teleostean; and I would provisionally associate it with the fishes from the upper Cretaceous of England and Syria assigned to the genus *Belonostomus*. From the latter it appears to differ only by the prominence of the vertical flutings upon the teeth."

The name *Belonostomus* (?) *indicus* may be suggested for this fish, if, as is probably the case, it proves to be distinct from the species hitherto described.

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Crystalline *and* Metamorphic Rocks *of the* Lower Himalaya, Garhwál *and* Kumaun, Section IV; *by* C. S. MIDDLEMISS, B.A., *Geological Survey of India.* (With two plates.)

THE IGNEOUS ROCKS OF RÁNIBÁGH, BHUWALI, AND KHAIRNA.

Following the practice begun in the earlier sections devoted to the subject of the crystalline and metamorphic rocks of the Lower Himalaya, I shall, in the present section, attempt to group together a few scattered observations on some igneous rocks from the above localities. In my memoir (Mem. Geol. Sur. of India, XXIV, Part 2) on the Sub-Himalaya of Garhwál and Kumaun, I have briefly referred to them for the purpose of elucidating certain facts relative to the Sub-Himalayan Tertiary rocks, but without going into stratigraphical or microscopical details.

The rocks to be described comprehend, on the one hand, granite, microgranulitic rocks, and porphyritic felsites; and, on the other hand, a widely-spread basic trap. The normal granite, so far, has only been seen at one point, namely Amratpúr, near Ránibágh. The microgranulitic rocks are well developed a little north of Amratpúr, also half a mile north-east of Bhuwali, and half a mile north of Khairna. Although these latter rocks have not as yet been traced continously between these three points, there seems no doubt that they are connected in reality, and that they indicate a line of strike running about N.N.W.—S.S.E. This line also corresponds to a similar strike indicated by the distribution of the extensive basic traps, which have their western boundary taking a course parallel to this. This boundary beginning near Ránibágh crosses the gap in the ridge at Bhuwali, through which the Ránikhet cart-road passes, thence to a little west of the Rátighát inspection bungalow, and thence cutting the Kosi river, some 2 or 3 miles west of Khairna.

The true order, as to age and superposition, of these rocks, as also of that of the interbedded quartzites and slates, is nowhere clearly demonstrated. A Himalayan section, especially of the older rocks, is never very clearly readable with regard to this all-important question of superposition; and in the present case the difficulty is more than ordinarily great, and many details have still to be worked out. The intense crushing to which the rocks have been subjected, and to which reference will be made presently, has frequently rendered undecipherable what might otherwise have been a clear section.

The following stratigraphical notes about the three localities and the intervening country, may, however, be of some ultimate service when united with further observations.

Amratpúr, near Ránibágh.—On the road from Ránibágh to Bhim Tál, as it winds along the north bank of the Gola river, are first seen evidences of these igneous and associated rocks, in the form of blocks of granite, microgranulite, trap, quartzite and slate from the hill-sides above. The granite alone, however, is found *in situ* by the side of the road, as far as where it leaves the vicinity of the Gola river near Amratpúr and turns away north. But a very beautiful section is laid bare in the side-stream which descends from Bhim Tál to the Gola river. These rocks are in contact with the Tertiary (Nahan) sandstone on the south, being divided from it by an east and west reversed fault (main-boundary fault).

In my memoir above quoted, I have referred to this condition of things, and shown that the case is simply one of old Himalayan igneous rocks brought into contact with the younger Nahan sandstone by the fault; and not one of intrusion of the igneous rocks among the Tertiaries. I think we may therefore start with that point as granted, and proceed to what is known concerning the surface order of the igneous rocks with which we are now concerned.

From the Balia N., near Ránibágh, to the stream from Bhim Tál, although the general line of the main-boundary can be traced pretty accurately, there are no very good sections sufficiently free from surface accumulations to be worth describing. The point to which I would direct attention is in the Gola river bed, east of the flat cultivated village land of Amratpúr, a very short distance south of the junction of the Bhim Tál stream with the Gola river.

The first of the igneous rocks north of the Nahan sandstone, and separated by about 20 yards of river gravel from it, is at the south end of a little line of cliffs, which bound the Gola river on its right bank, for a short distance below the Bhim Tál stream. It is a much crushed and distorted greenish rock, most probably a trap. It is too much crushed and decomposed to make sure of this, no trustworthy specimen being obtainable. Vein quartz ramifies through it, and portions of the quartz and also more stubborn portions of the trap, are converted into eyes, or lens-shaped masses, by the crushing it has sustained.

There are only 10 or 12 yards of this exposure, which is followed by a black clay or shale, perhaps one foot across.

These two rocks have evidently been so much powdered by pressure, and split parallel to the main-boundary fault, *i.e.* east and west, that nothing more can be made out concerning them. Their condition doubtless represents the mechanical disturbance caused by the fold-faulting which produced the main-boundary. To such a distance the influence of the Post-Nahan lateral pressure, which elevated the zone of Nahan sandstones, was undoubtedly felt by the older rocks.

Next to the black clay band comes the granite. At first it is rather grey in colour, but when traced north to the Bhim Tál stream along the cliff exposure, it becomes a purer white, in which felspar, quartz, and mica can be seen by the eye. Beyond a certain amount of jointing parallel to the line of the main-boundary, there is no trace of a fissile, schistose, or gneissose structure in this granite; a fact which the microscope confirms, as will be seen further on.

Continuing north up the Bhim Tál stream, there is a continuous exposure of naked rock, well preserved. The passage from the granite into a microgranulitic set of rocks seems at first sight to be complete. Certainly, so far as the behaviour of the two rocks to external agencies,—denudation, stream erosion, weathering, &c.—is an indication no difference can be detected. The two sets of rocks seem to be united into one *massif*. Close work with the hammer, however, showed that there was a line of division between the two, on the south side of which there was unmistakeable granite, and on the other side of which was a much more homogeneous and darker rock—the microgranulite. This divisional line is a little north (⅛ or $\frac{1}{10}$ mile) of the south end of the Bhim Tál stream. Although I insist on the separation of the two rocks here, it seems very probable that they have a subterranean connection somewhere.

The microgranulitic rocks continue up the stream for ¾ mile, when we come upon a dark-green basic rock. In the field I was almost persuaded that there was a passage up from the former into the latter. The microgranulitic rocks appeared to get darker, and greener, and more homogeneous, until, without any great effort of the imagination, they could be pictured as passing into the traps to the north. The microscope has shown this to be fallacious. The whole series of rocks collected south of what is undoubtedly a basic trap, is entirely distinct, and shows no trace of such a change as that.

The traps having set in, they continue the whole way up to Bhim Tál, sometimes strongly amygdaloidal, and sometimes interbedded with purple slates and hard purple or white quartzite. Throughout this distance of about 4 miles their divisional planes, which become a marked cleavage near the upper and lower surfaces of a flow, have a general direction N.N.W.—S.S.E. with the dip E.N.E. This is also conformed to by the amygdaloidal and compact beds, and by the interbedded purple slates and quartzites.

If the granite in the Gola river be traced east in the direction of Amia village, it is seen to gradually disappear against the main-boundary fault south of Amia in the river-bed, where there is a very good section of the micrograuulitic rocks, almost in contact with the Nahans. Both the Nahans on one side, and the micro-granulitic rocks on the other, are much cut up by divisional planes, and sinuous joints parallel to the main-boundary, which give the rock a coarse lenticular-tabular appearance. This complex series of divisional planes and joints may, in fact, be looked upon as constituting in part the main-boundary fault; which need not always be a single clean-cut fracture. These phenomena are only found in the immediate vicinity of the fault. The intimate structure of the rock under the microscope does not seem to have suffered in this way. It is not known exactly how far these microgranulitic rocks extend in the direction up the Gola river, but they are at least present west of Udhuan, next the main-boundary, after which their place is gradually taken by the basic traps, quartzites, &c.

In a westerly direction the granite is found ½ mile N.N.E. of the suspension bridge at Ránibágh; the microgranulitic rocks also outcropping on the hillside between that point and the trigonometrical station north-west of Amratpur. They both, of course, come to an end a little east of the Balia ravine by the fault (horizontal displacement) which brings in the Nahans (see map of Sub-Himalaya, with Memoir, G. S. I., vol. xxiv, pt. 2).

Bhuwali.—I will now describe such of these rocks as appear at Bhuwali. Their western neighbour, in this locality, is a great set of slightly agglomeratic slates—no doubt a less energetic form of the rock, called elsewhere by me a volcanic breccia, or ash—and a set of ordinary grey, carbonaceous, and purple slates, showing marked cleavage, which is only sometimes concordant with the bedding, and is often at right angles to it. These slates occupy large areas on the south-east and north approaches to Naini Tál. As to this slate series, there is no doubt that it underlies the massive limestone, which is a familiar feature at Naini Tál; the dip of the whole series between Naini Tál and Bhuwali being about due west at 30°. But the difficulty arises when we try to connect the volcanic series at Bhuwali with this agglomerate and slate series. Besides, there are not wanting signs that the relation between the two is that of discontinuity, either a break in time represented by an unconformability, or a fault of some nature. It is certain that near Bhuwali bungalow (Mr. Newton's) there is a complete change in the dip, introducing basic traps and quartzites, with a N.N.W. strike and an E.N.E. dip. These rocks, much cleaved in the above direction, hold the field all the way between the Bhuwali bungalow and Bhuwali village; and beyond that again they stretch over great areas E. and E.N.E. About ½ mile north-east of Bhuwali village, on the road to Almora, there comes in some microgranulitic rock.

It seems necessary to point out here that there is no visible connection between the agglomeratic slate and the set of volcanic traps, and microgranulitic rocks, notwithstanding that the former is certainly of derivative volcanic origin; for, in the first place, there are no interbeddings of the two rocks, and in the second place, although in juxtaposition here, they are not so in any other part of the country in which I have seen their respective representatives.

The cart-road connecting Bhuwali with Rátighát, during the first mile or so, passes over quartzites which are very nearly horizontal, and which have apparently dykes of trap cutting through them, but so very much crushed as to be unrecognisable. The dykes are thin, and appear to have suffered very considerably by the nipping between the jaws of quartzite. Further on, the E.N.E. dip in the quartzite becomes very high. A few miles south of Rátighát, the traps set in with greater force, and the quartzite with less. At Rátighát the traps are cleaved with a north and south strike, and a high dip of 60° E. The dip in the associated quartzites is in the same direction.

The traps and quartzites are abruptly cut off on the west by a grey slate series, in which the dip is 60° S.W.

From Rátighát to Khairna, the cart-road runs through these traps, exposing very good sections of amygdaloidal and plain bands, with a north and south cleavage, and a similar strike with dips to the east, which become E.N.E. near Khairna. The last mile is through quartzite alone, dipping in the same direction.

Khairna.—The quartzite just referred to is of a pale purple, and sometimes greenish colour, and often white. It is generally of rather coarse grain, and slightly conglomeratic, the conglomerate being made up of large quartzite pebbles. Intrusive dykes of trap, cutting through the quartzite in several places a little north of Khairna, are exposed on the cart-road. As at Bhuwali, the traps in these thin dykes have suffered very severely by nipping between the jaws of quartzite. Very occasionally the trap forming the dyke sends off veins, anastomozing with the quartzite, and partially surrounding portions of it, like the various confluent streams of a river. Sometimes, where the quartzite is conglomeratic, the dyke trap has worked its way between the pebbles. In the Kosi river bed, near Khairna, there are large blocks of this conglomerate. On first seeing it, a long time ago, I was struck by its resemblance to the Lobah conglomerate;[1] but, not having then found it here *in situ*, I was puzzled as to whence it came. The locating of it to what would appear to be a rather low horizon in this volcanic series, and near its western (probably faulted) boundary, is very suggestive of the similar position of the Lobah conglomerate with regard to the Volcanic series of that part of the country.

Further on, when treating of the microscopical characters of the rocks of this paper, it will be shown that the nature of the acidic and basic members of these rocks is very much akin to that of the acidic and basic series found at Lobah and already described by me.

About ½ mile north of Khairna, on the cart-road, these quartzites, conglomeratic quartzites, and their trap dykes suddenly come to an end; and there sets in a band of rocks which are exactly similar to the microgranulitic rocks of Amratpúr and Bhuwali, except that the matrix is slightly finer, and that they become intensely fissile on their south-western border: that is to say, they have been cleaved, with production of lenticular-tabular structure involving the porphyritic quartz and felspar crystals. The centre of the band of these rocks is, however, unaffected by the crushing, and in the hand specimen and in the field it very closely resembles the rock near Amratpúr and Bhuwali.

If, instead of going north from Khairna, we take the road along the Kosi river, up stream, we shall, at the appropriate place, according with the N.N.W. strike, come once more upon a very much cleaved representative of these microgranulitic rocks. We shall also find that the general dip of the rocks is still E.N.E., as shown by the

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[1] See Records, G. S. of I., vol. xx, p. 162.

bedding of the quartzite, by the cleavage of the rocks, which generally conforms to it, though not always, and by the inter-bedding of the various kinds of rocks with one another. In addition, we shall find more quartzites, apparently superposed on the microgranulitic rocks, above which then come basic traps and more quartzites

These stratigraphical notes, I am well aware, are wanting in precision in many points, as compared with the ideal descriptions entertained by me at the beginning of these sections on the crystalline and metamorphic rocks of this region; but I hope ultimately to clear up many doubtful points. At present, it is well merely to keep in our minds the following facts and lines of conjecture :—

(1) That these acidic and basic series, herein described, are equivalents of the acidic and basic series described in sections II and III near Lobah, and north and north-east of the Dudatoli area, I have no doubt. For, although there are no pure microfelsitic rocks here, as in the Lobah area, the porphyritic microgranulitic rocks, and porphyritic felsites have a very close representative in the rock described (section II) from near Marwara (specimen No. $\frac{7}{757}$), and are undoubtedly connected with other rocks from near the same place. These latter have not yet been described by me. In the field they gave me much food for thought, because of their general likeness to the gneissose-granite of the Dudatoli area There was a difference, however, which was very noticeable at the time : they were much more compact as to their matrix, and thinner bedded. Two specimens, one from 1 mile south-west of Khainoli (No. $\frac{7}{768}$), one from $\frac{1}{4}$ mile east of Jingora (No. $\frac{7}{770}$), have, however, been sliced; and under the microscope they show a somewhat scant microgranulitic or felsitic matrix, in which are very much corroded, singly twinned orthoclase eyes, and quartz granules. Both specimens appear to have suffered mechanical deformation, and become foliated, so that they bear a very great resemblance to the gneissose-granite of the neighbouring Dudatoli mountain. Associated, as they are, with a series of quartzites, quartz-schists, schistose slates, and beds of basic trap, which I consider to be younger than the Dudatoli micaceous and garnetiferous schists, for reasons before stated, it is very possible that they represent with the Marwara rock an acidic rock half-way between the gneissose-granite, on the one hand, and the microfelsitic, or rhyolitic rocks of Lobah on the other.

Briefly stated, the reasons in favour of the correlation of the Lobah volcanic rocks with these of Khairna, Bhuwali and Amratpúr, are the following :—

(*a*) Similarity of composition.

(*b*) The dual order of an acidic and basic series.

(*c*) The correspondence in strike, both of bedding planes, and cleavage or foliation planes.

(*d*) The presence of associated quartzites and slates, the former bearing a coarse conglomerate.

(*e*) A sharp-faulted boundary on the west, separating these volcanic rocks from others which have a dissimilar strike and method of disturbance.

(2) Accepting this local correlation as having many points in its favour, we have to bear in mind the fact that in the Lobah area these rocks overlie, with a great unconformability and attendant quartzite conglomerate, a dark, blue-grey, massive limestone. That this can be nothing else than a normal order of superposition seems proved by the fact that the massive limestone appears beneath these volcanic rocks

as a dome of outcrop, not more in places than half a mile across. The question then arises, Is this massive limestone the same as the Naini Tál massive limestone, with which it agrees petrologically? In the Lobah area, only a short thickness of the limestone is exposed, and none of the lower beds. But what is palpably a continuation of that limestone, on the Dhanpúr ridge, has underlying it a slate series, ed by purple colouring in places, and in all ways agreeing with that underlying the Naini Tál limestone. In addition, the volcanic breccia is also represented near Dhanpúr, associated with these slates.

There are certain points, therefore, strongly supporting the theory of the oneness *of these two limestones; and that, therefore, the set of volcanic rocks described in* this paper belong normally to a position above the Naini Tál limestone.

(3) Opposed to this view is the opinion of Mr. R. D. Oldham, that in other parts of the Himalaya there are two distinct massive limestone series, alike petrologically, but of distinct age and horizon; the lower being called the Deoban limestone, and the upper the Krol.

In view of the local nature of these petrological studies of the Lower Himalaya, I hope I may be pardoned for leaving the matter in this tentative stage.

I shall now describe an illustrative series of specimens from the localities mentioned in the sub-heading; the numbers, as in previous papers, being generally those of the rocks as registered in the Geological Survey Museum.

No. $\frac{8}{347}$. *South edge of plutonic band, east of Amratpúr, Gola river.*—This rock in the hand is a grey, coarsely crystalline rock. Under the microscope it is seen to be a coarsely crystalline granite, containing orthoclase, quartz, and white mica, all grouped in their normal order, and in the method of crystallisation familiar in all granites.

The felspar is often present as regular, singly-twinned crystals, from which its species can be determined as orthoclase; but more often it is partially or entirely divided up into portions which behave optically as a felspar, and which are separated, or surrounded, by a finely granular aggregate. This finely-granular aggregate often winds its way along cleavage cracks in the felspar, and appears due to some hydro-chemical alteration. In some of the microgranulitic rocks to follow, nearly all the porphyritic felspars have been thus altered, though retaining unaltered their crystallographic outline. Under polarised light the effect is generally that of a fine aggregate, among which, points showing brilliant colours may be secondary cryptocrystalline mica.

The quartz is in large irregular grains filling in cavities between the other minerals. It is full of lines of minute inclusions, which give it a streaky, dusty, appearance. With a one-eighth inch objective their nature remained unsolved.

The white mica is present in small quantities, with slightly bent folia.

Magnetite is almost entirely absent, there being but a few specks, chiefly aggregated or included with the mica.

There is no trace of foliation in the rock, nor violent cataclastic action; although the specimen was taken not more than 30 yards from the main-boundary fault.

No. $\frac{8}{349}$. *Junction of Bhim Tál stream with the Gola river.*—In the hand this is seen to be a very good, normal, white granite, without any gneissose aspect whatever, nor any appearance suggesting that differential motion of the particles of the rock over one another due to pressure, or other causes, had ever taken place. As an excellent ornamental stone, I wonder that it has never been quarried, especially considering its proximity to the rail.

Under the microscope the coarsely granitic texture and composition of the rock is confirmed.

The felspar is much altered, as in the last specimen, but into a yellowish-brown material, dusty in appearance, or finely granular, among which portions of the original unaltered felspars can be seen, especially in certain parts of the slice. In other parts, all trace of the original felspar has gone, leaving only the alteration product, which however indicates its real nature by polarising uniformly as a single crystal. This, however, is sometimes very faint. There are, in fact, all gradations, from a fairly well preserved felspar to one entirely unrecognisable either by ordinary or polarised light.

Most of the felspar is orthoclase, but a few examples of the triclinic group are present, exhibiting, through the grey alteration product, a true and very fine lamellar twinning. The species could not be determined.

The quartz, as in the last slice, is in large, bold, irregular grains, traversed by lines of cavities of very minute dimensions.

White and greenish-brown mica are present, with the prominent basal cleavages oriented in all directions, and grouped together.

Magnetite is as scarce as in the other specimen, but is aggregated more freely in the biotite.

No. $\frac{8}{381}$. *Half mile N.N.E. of Rânibâgh.*—In the hand this specimen might be either a granite, gneiss, or arkose. Under the microscope it is seen to be a granite, coarse in grain, and much of the type of the two preceding examples, with, however, one difference. There is more of the coloured mica, which is of a strongly greenish-brown tint; and it seems to have suffered a secondary change, whereby the substance of one crystalline packet has been carried and re-deposited along cracks running through and between the quartz and felspar. This is very noticeable all through the slice. These canals of secondary mica are known by their colour and connections with the well-cleaved packets; for otherwise they have no definite crystalline properties.

A few scattered prisms of apatite can be detected with high powers.

No. $\frac{8}{380}$. *A little north of junction of Bhim Tál stream with the Gola river.*—This rock, as already explained, is apparently united into one *massif* with the granite to the south, although close work in the field served to separate the two by a fairly sharp boundary. In the hand it is seen to be darker in colour than the granite, and more hazy as to the contained minerals.

A slice under the microscope shows this difference to be due to the fact that the present rock is a porphyritic one, with a microgranulitic ground-mass. The porphyritic constituents, however, are identical with those in the granite, with the exception that white mica is not represented.

The felspar crystals, with fairly rectilinear outlines, and floating, as it were, in this microgranulitic matrix, are extremely opaque, and could scarcely be recognised here were it not for the analogy of other slices. There is no doubt, however, that they are highly altered felspar and mainly orthoclase. Sometimes faint remnants of cleavage can be detected in them, but not often.

The porphyritic quartz has suffered considerably by corrosion at the edges and along cracks, so that it presents a worn boundary with numerous bays and included portions of the microgranulitic ground-mass. Evidently it was solid and crystalline, whilst the matrix was still molten. The internal structure of the quartz (lines of cavities, &c.) is the same as that of the granite.

A greenish mineral in ragged blotches, sometimes with a nucleus of undoubted biotite, lies in irregular nests among the ground-mass.

Portions of it, and minute grains of magnetite, are dotted about in the microgranulitic ground-mass, which in coarseness lies between a fine-grained elvan and a felsite. I think there can be no doubt that this rock is an intermediate form between the granite and a purely felsitic or rhyolitic rock.

A few cracks in the porphyritic elements carry with them very occasional displacement, but not more than need be satisfied by slight motion in a semi-solid rock substance.

No. $\frac{8}{351}$. *Bhim Tál stream ¼ mile from junction with Gola river.*—A dark, purplish-grey, mottled rock. Microscopically it shows little variation from the last described. It is a microgranulitic rock, with porphyritic felspar and quartz, and with nests of mica. Some of the porphyritic felspars retain their cleavages, and power of polarising light, to a rather more marked extent, and sufficient to enable the species to be recognised as orthoclase. Generally, however, it has the prevalent, dusty, opaque appearance, the result of alteration. The boundaries of the felspar are much corroded away in places, as are those of the quartz. The latter, besides, possess inlets and large inclusions of the microgranulitic ground-mass.

Apatite, in minute prisms, is present in the ground-mass, and also included in the felspars.

The purplish colour of the rock is due to some of the quartz being amethystine.

Dotted in the micro-granulitic matrix are specks of magnetite, and, as it were, shreds of greenish-brown mica, which, though minute, frequently exhibit dichroism and their proper cleavage.

No. $\frac{8}{352}$. *A little north of the last specimen.*—Resembles the foregoing macro- and microscopically. The porphyritic felspars are darker and dustier; the magnetite is in larger blotches, with sharp boundaries; apatite is present; and the mica is yellowish-brown in colour, and strongly impregnates the ground-mass in minute but well-recognisable patches. There are also some larger packets of it, whilst some of the nests are filled, not with a single large packet, but with a great number of small ones oriented in all directions. The ground-mass in the vicinity is riddled and penetrated in all directions by this microcrystalline mica.

No. $\frac{8}{353}$. *Three-fourths of a mile E.N.E. of Ránibágh on the Bhim Tál road.*—This is very similar to the last. The mica is, if anything, slightly better preserved. The felspar is in very good shapes, often twinned. A peculiarity (depicted fig. 1, plate I) of some of these is, that, though the outline of the crystal is very sharp, only the central portion, or the central portion of a twinned half, is left pellucid and optically perfect with regard to polarised light, the rest of the crystal having suffered alteration to the fullest extent.

No. $\frac{8}{354}$, *Bhim Tál stream ½ mile from Gola river*, and No. $\frac{8}{355}$, *A little further* *north.*—These two resemble the other members of this microgranulitic group; except that in the former the mica is in more confined crystallised forms, and of bright grass green colour; and that in the latter the felspars are pale grey and mottled, and entirely inactive under crossed nicols.

No. $\frac{8}{388}$. *Bhim Tál stream ¼ mile from Gola river.*—This rock differs in some ways from what have gone before. The ground-mass is much the same generally, but fine in grain, and almost felsitic rather than microgranulitic. The porphyritic elements in it have suffered more by corrosion in the magma than heretofore. Even the felspars have almost entirely lost their natural crystallographic outlines, and become bounded by sinuous lines, and with numerous inbayings of the ground-mass. The substance of the felspars has also become more hopelessly altered, so that in not one of them can there be traced the slightest uniform darkening when the slice is revolved under crossed nicols.

The green mineral is of pale colour, and in restricted patches; but without any cleavage, or action, under polarised light. Blotches of magnetite, of large dimensions, are present in the green mineral.

To the north of this specimen the basic traps set in suddenly, as already mentioned; but I shall now pass on to the acidic rocks of the other localities, taking all the basic rocks together at the end.

No. $\frac{8}{389}$. *South bank of Gola river opposite Amia village, 20 yards from main-boundary.*—This rock is dark grey in colour, and penetrated by lighter-coloured felspathic veins. It is introduced here, as being in close proximity to the main-boundary. Under the microscope the rock is best represented by No. $\frac{8}{381}$, described previously. The points noticeable in it are that, although so near the main boundary fault, and although the rock in the field is cut through by sinuous joints and lines of displacement parallel to the junction of it with the Nahan sandstone; still, beyond a few slightly parallel cracks in the slice along which the mica has been carried and re-deposited, there are no other signs of violent cataclastic action. In fig. 2, Plate I, I have sketched a corroded quartz granule from the rock. The bays and capes, so manifest in that quartz island, show no abrasion nor destruction later than that due to the corrosive action of the molten magma. The porphyritic felspars in the same way, though much corroded, and their outline gone, have never been crushed *in situ* by any violent cataclastic action.

No. $\frac{8}{390}$. *North bend of Gola river between Amia and Jamirani, also near the main-boundary.*—This is very similar to the above. In fig. 3, plate I, I have drawn a quartz, which possesses an outline of tempting corners, and angles that would certainly have been carried away by any severe dynamic crushing. A few parallel cracks occur, however, in the rock, as in $\frac{8}{389}$.

The bearing of the facts noted about the last two specimens needs a little explanation. The point which I have tried to make is that, though these granitic and microgranulitic rocks have been slightly crushed and jointed in the neighbourhood of the main-boundary fault, they have not suffered a rearrangement of their particles at any one or other position in the band of igneous rocks so far described: there are neither cleavage, schistose, nor violent cataclastic structures to be found in them. We shall therefore be prepared, when we subsequently find these structures developed elsewhere in similar rocks, to accept them as the result of other forces totally distinct from those which produced the main-boundary fault, or which subsequently acted on the Himalayan area.

I will now take next in order the band of micrograntulitic rocks ½ mile north of Khairna, skipping the Bhuwali rock for the present, as it exhibits effects of considerable crushing. The Khairna band also exhibits intense crushing through much of its thickness, but near the centre there is a comparatively massive variety, more nearly resembling the rocks in the Bhim Tál stream than any of the others. Taking that for description first, it will be easy to pass by stages to the fully crushed and foliated varieties.

No. $\frac{8}{369}$. *Near centre of band ½ mile north of Khairna.*—In the hand it appears mottled in various shades of greenish-grey, and contains large grains of felspar and quartz, some slightly eye-shaped. There is no sign of a fissile structure about it.

Under the microscope the ground-mass closely resembles that of $\frac{8}{356}$. It is rather finer than a typical microgranulitic rock, resembling rather a felsitic or petrosiliceous rock.

The porphyritic felspars are not very well preserved, either as to their material or their outlines. Sometimes a central part of a broken crystal behaves optically as a felspar of the orthoclase species, whilst one example showed distinct twinning lamellæ. As a rule, the felspars have been fissured in a wavy parallel direction, and slight movement has followed, resulting in the partial aspect of eye or augen structure. The quartzes are much more intact, though corroded to a great extent and sometimes slightly fissured.

The greenish mineral is not recognisable as mica, though doubtless that was its species originally. It runs about through fissures in strings, with a moss-agate-like aspect, and is sometimes aggregated into nests and associated with rather large grains of magnetite. It and the magnetite are rather more plentiful than in the previously described specimens.

No. $\frac{8}{370}$. *From near the same locality.*—Macroscopically it resembles the last specimen. Under the microscope the ground-mass is finer and darker, almost typically felsitic, with traces of flow structure. The felspars are somewhat better preserved, two of which in the slice are triclinic. All, however, are altered marginally, centrally, or irregularly at one point or another. One triclinic felspar, with broad lamellæ, had the latter bent as in the drawing (fig. 4, plate I). The quartz in large porphyritic grains, and other smaller ones, is typically that of a quartz felsite, though the crystallographic outlines are not preserved. In fig. 5, plate I, I have sketched a portion of one large grain with small inclusions, or inbayings of the ground-mass.

The green mineral is confined to nests, and strays about the rock to a rather less degree than in the last specimen.

Magnetite, as before, is associated with it in rather large grains.

No. (30). 609.[1] *Three-fourths of a mile north of Khairna.*—It completely resembles either of the foregoing two specimens. There are no unaltered felspars, and the quartzes are much the same. The ground-mass is rather clearer and coarser. Apatite is present, but very scarce.

No. $\frac{8}{368}$. *About ½ mile north of Khairna.*—In the hand this rock exhibits lenti-

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[1] The numbers in this case and similar cases, where the rock has not been registered, are my own running number (in brackets) followed by the number of the microscope slide.

cular-tabular foliation on a rather small scale. It is of pale, greenish, and mottled colours. Under the microscope the above structure is confirmed. The greenish mineral lies along the foliation planes, cutting through the ground-mass. The latter is very fine grained in parts, but shows a mottling of patches fading into one another, which suggest remnants of broken felspars.

All the larger felspars show a drawn-out, bent, or eye-shaped aspect; and they merge indistinctly into the ground-mass. Individually, also, they are cut through and through by wavy lines, parallel to the foliation, and helping to constitute it. The quartz granules are more intact, but they are surrounded by a halo of quartzose powder, which, seen under crossed nicols, gradually merges them into the matrix (see fig. 6, plate I).

I should say this rock was undoubtedly a porphyritic, microgranulitic, or felsitic rock, which had been finely foliated by pressure, with production of well-marked lenticular-tabular structure.

No. $\frac{8}{367}$. *South edge of band $\frac{1}{9}$ mile north of Khairna.*—In the hand this rock is rather soapy to the touch, and it is evidently more finely cleaved than the previous rock. Under the microscope this is borne out by the very fine lenticular-tabular foliation, which cuts up the rock in parallel sinuous lines, and by the crushed and drawn-out extremities of the quartz grains (see fig. 7, plate I). The latter are small, and there are no porphyritic felspars visible. Certain indications point to the probability that the latter have been entirely lost and mixed with the ground-mass by the crushing which the rock has sustained. Magnetite is drawn out into shreds.

No. $\frac{8}{366}$. *Same locality as the last.*—Very similar to the last, the fissile structure being well marked, and the drawing out of the quartz-grains and magnetite most prominent (see figs. 8 and 9, plate I).

No. $\frac{8}{365}$. *Near same locality as the last.*—In the hand a fairly well marked cleavage is present, with prominent eyes of quartz, dark grey in colour. This slice, seen under the microscope, possesses a fine grey matrix, cut through and through by wavy foliation lines. The porphyritic elements are quartz and felspar, both of which are broken up into fragments, which are visibly displaced until they merge into the matrix. The quartz, however, has not suffered so much as the felspar. The latter indeed, crossed and re-crossed at small angles by lines of movement, has become very much dispersed among the matrix, such that a little more crushing would have made it vanish as a separate entity, and given the rock the appearance of the last two slices.

No. (34) 613. *$\frac{1}{2}$ mile N.E. of Bhuwali village.*—Outwardly this rock resembles No. $\frac{8}{368}$ very closely. It is very pale green in colour, the foliation being visible.

Under the microscope, or when the slice is merely looked at through a hand lens, it can be seen to be a rock typically foliated on the lenticular-tabular pattern. Nearly all the felspars in the rock have lost their proper shape, and become dragged out into elongated lenticular bodies, by the layers into which they have split stepping over one another as if by a series of nearly horizontal step-faults. The quartz has not suffered so much; and it seems to be a rule that when any remnants of felspars remain in these rocks, a less energetic crushing is indicated, not quite sufficient to have pounded up the harder free quartz. In the drawing (fig. 1, plate II) is indicated the mode of disturbance of the felspars in this rock.

A large quantity of the green mineral follows the foliation in an irregular, wavy manner. Magnetite is rather plentiful in the slice, in large grains, more or less aggregated together, and smudged out with the foliation.

No. (35) 614 and No. (37) 616. *From the same locality as the preceding slice.*—Outwardly these two rocks have much the appearance of No. $\frac{8}{389}$ from Khairna, that is to say, they are more massive, and show but slight lenticular-tabular foliation. Under the microscope the rock is seen to be cut through by a few divisional planes, but they are not so closely packed together as in the last specimen. Veins of secondary quartz run along with the green mineral, parallel to the foliation.

Some few felspars which are visible, are slightly broken *in situ*, but have not been displaced to any extent.

The quartzes are not quite so whole as before, nor of one uniform crystal, but are a coarse polysynthetic aggregation, especially in (35). In (37) considerable disruption of the quartz and felspar grains is noticeable, but they have not been dragged out into lens-shaped bodies.

In other respects the rock slices resemble No. $\frac{8}{389}$ very closely.

It will be noticed that throughout the foregoing foliated and cleaved varieties of the micro-granulitic and micro-felsitic rocks, I have asssumed that pressure was the cause of the fissile structure. In a certain measure the structure has undoubtedly the appearance of flow structure (in one sense it is indeed flow structure, but such as has been demonstrated to take place in solids when subjected to sufficiently violent pressure), but it seems to me to differ radically from what is known ordinarily as flow structure in a volcanic rock, in this respect. All rocks that I have seen exhibiting flow structure (due to their once molten condition) never show any susceptibility to split along the direction of flow; or, *vice versâ*, a rock may be perfectly compact to the eye and touch, and yet possess a marked flow structure within. Now, in all the cases I have enumerated above from the Khairna and Bhuwali neighbourhoods, either the particles of the rock are discontinuously separated along the planes division, or they are potentially separated, and may be made actually so, by (for instance) a blow from a hammer.

It would also be a stretch of the imagination to believe that such shattering of the quartzes and felspars as I have depicted could have been produced by a force transmitted through a semi-solid or molten medium.

Besides this, in my previous paper (section III) on the crystalline and metamorphic rocks of the Lower Himalaya, I have shown, by a different line of reasoning which need not be repeated here, that all the fissile structures of the rocks therein described have been produced since the solidification of the rock, and that therefore they were not produced by differential movements of the particles whilst in a molten or viscid state.

Leaving the acidic series and coming to the basic traps, I shall confine myself to a few examples.

No. $\frac{8}{357}$. *Bhim Tál stream, ¾ mile north of Gola river.*—This rock in the field comes next to the microgranulitic rocks, and, as stated above, is really entirely distinct from them. It is a dark-green finely crystalline rock, viewed macroscopically.

Under the microscope it is seen to be a completely holo-crystalline aggregate of triclinic felspar and augite, with a little hornblende, and with a small amount of quartz filling the interspaces, and magnetite in large, sharply-bounded forms. The felspar and augite are in large crystals which mutually interfere with one another, forming a coarse-grained felt-work of gabbro-like texture.

The felspars are very much altered into a grey dusty-looking substance, which prevents their having any effect on polarised light. Only by their lath-shaped forms, their mode of aggregation, and their associations can they be deemed to be triclinic.

The augite is of very pale yellowish brown, almost colourless tints, frequently singly twinned. The cleavage cracks are exceedingly well marked, and in many instances a diallage cleavage is superadded of fairly intense character, but not sufficiently so to make the mineral merit the name of diallage. Here and there in the slice a greenish-brown dichroic mineral is seen, with, in one place, the prismatic cleavages of hornblende. It is inseparable from the augite, and fades into it by transition tints, so that there is little doubt that it was originally derived from the augite.

The habit of the quartz indicates its secondary origin as an alteration of the felspars. The presence of a connecting train of smaller granules uniting it with a quartz-pegmatoid structure occupying a felspar shape also points to the same conclusion.

This rock, in structure and composition, is so like the Limeri rock[1] near Rudarpræg (No. $\frac{7}{788}$), that they might pass for one another. The Naini Tál trap (to be described in a subsequent paper) is also very similar.

No. (38) 617. *Three miles south of Bhim Tál, on the Ránibágh road.*—This rock outwardly resembles any of the Rudarpræg traps described in the paper last referred to. It is a micro-crystalline aggregate of triclinic felspar needles, and bundles of needles, together with a greenish-brown mineral altered beyond recognition. In addition, there are lacunæ filled with viridite, and sometimes large amygdules filled with the same; also opacite in small specks and rods. The felspar is oligoclase, judging by the extinction angles of the microlites.

There may be a small amount of uncrystallised base remaining, but it is impossible to pick it out from the altered green mineral.

There seems no doubt that this was once a lava flow.

No. (33) 612. *Little north of Bhuwali.*—A fine-grained, dark-green rock. Under the microscope it is rather coarser in grain than the last, but appears to be constituted of the same elements, and needs no separate description. It appears to have been greatly altered. The felspar, being somewhat larger than before, has suffered slight alteration, so that the polarisation phenomena are weaker: a similar peculiarity was noticed among the felspars of the Rudarpræg neighbourhood.

A very faint cleavage is recognisable, with slight parallelism of the felspar micro-crystals.

No. (39) 618. *South of Malwa Tál,* $\frac{1}{8}$ *mile.*—This rock is petrologically a cleaved variety of $\frac{8}{387}$. It is introduced here somewhat out of place, because of its illustrating the same sort of crushing which has affected the microgranulitic rocks.

The quartz and the felspar are dragged out into lenticular bands, and somewhat mixed one with the other; but the augite, with its typical cleavages, shows better than anything else, by the elongated lenticular bands into which it has been forced, how

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[1] Records, G. S. of I., vol. xxi, p. 18.

powerful was the force that, as it were, rolled out the crystalline contents of the rock. like the separate layers of puff-pastry (see fig. 2, plate II).

In Section III of these petrological studies I have given so many examples of the cleaving and foliation of the more compact and amygdaloidal varieties of the basic traps that the previous example of a holo-crystalline basic rock having suffered the same, is sufficient in this place.

REFERENCES TO PLATES.

Plate I, fig. 1.	Altered crystal of orthoclase, with unaltered central portion, from a slice of specimen No. $\frac{8}{383}$, as seen in ordinary light.
„ „ 2.	Corroded quartz in micro-granulitic ground-mass, from a slice of specimen No. $\frac{8}{389}$, seen under crossed nicols.
„ „ 3.	Corroded quartz grains in micro-granulitic ground-mass, specimen No. $\frac{8}{380}$, under crossed nicols.
„ „ 4.	Triclinic felspar, with bent lamellæ, in micro-felsitic ground-mass, specimen No. $\frac{8}{370}$, under crossed nicols.
„ „ 5.	Edge of quartz grain, showing effects of corrosion by the magma, specimen No. $\frac{8}{370}$, under crossed nicols.
„ „ 6.	Quartz grain, with powdered margin, in foliated micro-granulitic ground-mass, specimen No. $\frac{8}{388}$, under crossed nicols.
„ „ 7.	Quartz grain, with powdered and drawn out extremity in highly cleaved micro-felsitic ground-mass, specimen No. $\frac{8}{387}$, under crossed nicols.
„ „ 8 & 9.	Further examples of broken, and drawn-out quartz grains, and magnetite in shreds, in highly cleaved micro-felsitic ground-mass, specimen No. $\frac{8}{388}$, under crossed nicols.
Plate II, „ 1.	Example of lenticular-tabular foliation cutting through, and altering the contours of porphyritic felspars in a slightly cleaved micro-granulitic ground-mass, microscope slide No. (34) 613, in ordinary light.
„ „ 2.	Example of lenticular-tabular foliation in a holo-crystalline basic rock, microscope slide No. (39) 618, in ordinary light.

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Note *on the* Bivalves *of the* Olive-group, Salt-range; *by* Oberbergrath Prof. Dr. W. WAAGEN.

When I came first to the Salt-range in 1871, the sequence of the beds exposed in this region had been made out in a satisfactory manner by Mr. Wynne, according to the data then available, and though in consequence of later discoveries some changes were unavoidable with regard to Mr. Wynne's original views, yet for the time Mr. Wynne's work was the best that had been executed up to then on the Salt-range. This is the best testimonial that can be attributed to a scientific work, as it cannot

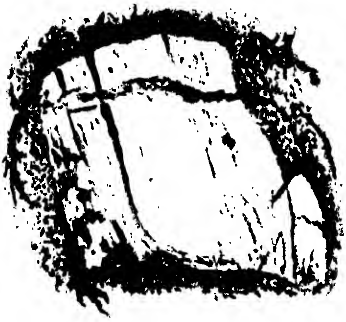

Plate II.

be expected of a man to anticipate everything that during further studies of eighteen years may be discovered. All human knowledge is attained by degrees, and thus every scientific work can only be expected to be absolutely correct for the time at which it is written, and any author cannot be blamed for not having discovered everything at once, because time is a very great factor in the human power of perception.[1]

At the time of which I am writing, Mr. Wynne had, among other rock groups, also distinguished one to which he had given the name "*Olive-group*" on account of the prevalence of olive-coloured sandstones within this group at certain parts of the range. Fossils were but very little known to exist in this group, except a few bivalves of uncertain affinities.

In the first excursions I made with Mr. Wynne to the range, we soon found that the beds in which *Terebratula flemingi*, Dav., occurred belonged to this Olive-group, and this furnished the first clue towards considering these beds as upper mesozoic, probably upper cretaceous. The large bivalves that had formerly been found at other localities by Mr. Wynne appeared not contradictory to such a supposition, as on a superficial inspection they showed forms much resembling the species of *Unio* found in certain mesozoic beds (Laramie and Jurassic) in North America. So, I myself suggested to Mr. Wynne, on the strength of the data then available, that the Olive-group might perhaps best be considered as topmost cretaceous, and this suggestion was published by Mr. Wynne in his Salt-range Report.

When the Salt-range materials came afterwards into my hands for description, it was absolutely impossible to work up all the materials at once; hence I had to divide them according to the different volumes into which I had proposed to divide the whole work: thus the Olive-group bivalves came among the lot that was destined to be described in vol. iii, and were packed away without any close examination.

In 1885, however, Dr. Warth made a most important discovery in the Salt-range, which was apt to suggest another view to be taken with regard to the Olive-group. He found in the boulder beds at the base of the group a number of nodules, as well as pebbles, in which palæozoic fossils were contained; and I myself have shown, in vol. xix of the Records, that these fossils exhibited a great affinity to Australian carboniferous species.

The green sandstones in which the bivalves occur, and which follow immediately above the boulder bed, I considered yet of probably mesozoic age; whilst others, before all Mr. Wynne, took also the boulder beds as of a similar age, because the "Conularia-pebbles" were considered by them as in a secondary position, and not fit to determine the age of the bed in which they were found.

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[1] Dr. Waagen seems unable to divest himself of the idea that he must needs be Mr. Wynne's apologist. There can be little doubt that Mr. Wynne is quite willing to admit that subsequent research has and must continue to alter or otherwise effect some of the conclusions given in his Memoir on the Salt-range. The recent discoveries tell somewhat against each author in his own line of work, but the facts remain, and on these the geology of the range must rest, not on *apologiæ*. Certainly, Mr. Wynne's work or writings have little, if any, direct bearing on the main point of the present paper which is really the story of the working out and recognition of the bivalves which have so long baffled Dr. Waagen's research.—ED.

Dr. Warth, however, was of a different opinion. In a paper published in vol. xx of the Records, he not only identified the boulder bed of the Olive-group with similar beds at the base of the Speckled Sandstone in the western parts of the range. as had been done formerly also by myself; but he also put the green sandstones with the bivalves on a parallel with green sandstone beds of the Speckled Sandstone, and yet higher following red sandstones, with similar rocks of the same western group.

With this paper of Dr. Warth's, the whole question was put in a new light, and I now proceeded to inspect those bivalves, which all of a sudden appeared as of the greatest geological importance.

After seeing these specimens again after so many years had elapsed, I was again struck by the similarity they exhibited to an inflated species of *Unio*. In none of the specimens was the hinge visible, and the material was of the brittlest kind imaginable, the rocks being generally considerably harder than the specimens. For nearly a year I tried every method imaginable to arrive at a clear view of the hinge, but for a long time quite in vain. At last I succeeded in cleaning the greater part of the hinge of both valves, and now the very strange result came to light that there existed no similarity whatever to *Unio* or any allied genus, but that the shells had to be rather approached to *Mytilus*, *Avicula*, or something of that kind, though the affinity still seemed to be a very doubtful and conflicting one.

I looked up all kinds of manuals and all sorts of books, without finding anything similar, except, perhaps, the genus *Modiomorpha* of Hall, but also here a very remote similarity only existed. At last I took the shells to Vienna, and showed them to everybody there, but without a better result.

After this I put them aside, disgusted, hoping that in the future the riddle might be solved, and began to write down the description of the contents of the Conularia nodules for vol. IV of the Salt-range fossils. For this purpose I got also Strzelecki's Physical Description of New South Wales to hand, and there all of a sudden I found a shell figured under the name of *Eurydesma* which was extremely similar to the Salt-range bivalves. The genus, I now found, was mentioned in all Hand-books, but, according to Dr. Stoliczka's views, was placed generally in the family *Tridaenidæ*, whilst all my observations on these shells pointed to a relation with the *Aviculidæ*.

After the spell had thus been broken, it was not difficult to follow the clue obtained; further, I now soon found that one of the species occurring in the Salt-range could be identified with all possible certainty with *Eurydesma globosum*, Dana, from Illawara, and this is an identification of such geological importance that I thought it worthy of giving a notice of it in the Records.

Now at last we know for certain that Dr. Warth's views in the matter were correct, and that the green sandstones, with bivalves, that formerly had been attributed to the Olive group, form in reality part of the carboniferous period. There is now also no need for further discussion about the question, whether the Conularia nodules were found *in situ* or not, as the *Conulariæ* occur either (in most cases) in a lower position than the bivalves, or (exceptionally) they are to be met with in thin seams between the beds of bivalve sandstone. The Conularia nodules, as well as the bivalve sandstones, both have now been found to contain species identical with such of the Australian carbonifeous; and with regard to the latter there has never existed the slightest doubt as to their occurring *in situ*.

I accept therefore the sub divisions of the Speckled Sandstone, as proposed by Dr. Warth, and the sequence of beds within this rock group is now the following:—

(6), Green and dark sandstones, with some limestone bands (Lower Productus Limestone).
(5), Red and purple clays (Lavender clays).
(4), Red sandstones (Speckled Sandstone properly speaking).
(3), Green sandstones.
(2), Darker shales.
(1), Crystalline-boulder conglomerate.

It can now no longer be doubted that the boulder-beds throughout the Salt-range belong to one and the same geological horizon, and are of upper carboniferous age; as in the eastern parts of the range their geological position can be demonstrated by the identity of the fossils with Australian carboniferous species, and in the western parts by their sequence below permian and uppermost carboniferous strata.

From the beginning, I have compared these boulder-beds with those of the Talchirs of peninsular India, but now that it has been proved that the green sandstones above belong to the same group of rocks, and that both rest unconformably on Cambrian beds, which, with some probability, can be put on a parallel with the Vindhyans of peninsular India; the points of similarity have augmented to such a degree that even sceptic minds will admit that the divisions 1, 2 and 3 of the Speckled Sandstone will probably have to be placed on a level with the Talchirs. To this comes yet another point of importance. Now that it has been proved that the Australian carboniferous species occurring in the Salt-range are *in situ*, and not in a secondary position; the identity of the Australian and the Salt-range strata containing the same species cannot be doubted any longer. In Australia, glacial deposits have been detected in these beds by Mr. R. D. Oldham; and for this reason they were also placed on a level with the Talchirs.

Thus, from all sides come in proofs for the identity of the lower part of the Speckled Sandstone with the Talchirs; and in such a manner a distinct horizon is fixed, from which to start for the comparison of other beds of peninsular India with the marine deposits of the Salt-range.

Notes *on the* Mudbanks *of the* Travancore Coast, *by* PHILIP LAKE, B.A., *Geological Survey of India.*—(With one plate.)

The mudbanks, or smooth-water anchorages, of Alleppy and Narrakal on the Travancore-Cochin coast, have been known for many years, and much has been written about them. A very full account of the literature of the subject has been given by Dr. King, in the Records of the Geological Survey of India (vol. xvii, pp. 14-27), and to his paper I must refer for a general account of the banks.

The chief object of my visit was to see in what way the bursting of the south-west monsoon and the rising of the backwaters affected the condition of the mudbanks. It unfortunately happened, however, that this year (1889) the monsoon did not begin at Alleppy with its usual suddenness, and the season was consequently not very favourable for my purpose.

As most of my time was spent at Alleppy, it will be best, first, to give an account of what I saw there, and then to describe the few observations made at Narrakal. To Mr. Rohde, the present Commercial Agent at Alleppy, I am indebted for several important observations and much valuable help, and especially for a table showing the changes of height of the backwater during the days of my stay. It is to the observations of Mr. Rohde and of his predecessor, Mr. Crawford, that we owe most of our knowledge of the Alleppy mudbank, and there is little to add to what they have already recorded.

The mudbank at Alleppy, though some miles long, is mostly hidden under the sea, and only a very small part of it appears above the surface. The actual northern end of the bank, which is some distance from shore, seemed to remain at the same point throughout my stay at Alleppy; but the visible part of the bank moved gradually southwards.

On the 4th June, mud appeared close to the pier, and the water there was very thick and smooth. For a considerable distance out to sea, and along the coast, though no mud was visible, the water was much smoother than in the open ocean. About half a mile north of the pier, the sea came in with its full force and with a great surf. The northern end of the mudbank, as was afterwards proved, lies almost directly off this point.

The smooth-water tract was semi-circular in shape, and its northern and southern edges were defined by two crescentic lines of breakers running outwards to the sea; but towards the west there was no distinct boundary between the smooth and the rough water. The waves became lower and lower as they approached the shore.

Where the water is smooth, the sandy shore is wide, and slopes gently to the sea; but where there is a surf, the shore is narrower, and the part of the beach upon which the waves break is very steep.

On the 7th the visible part of the mudbank had moved a little to the south; and one of the peculiarities of the waves, as they approach the bank, was very clearly marked.

About half a mile north of the pier the waves came in with full force, and their crests were parallel to the shore. When, however, a wave passes over the mudbank, not only is its height diminished, but its velocity becomes less. The southern part of a wave is here over the mudbank, while the northern part is still over a sandy bottom. The part over the mudbank is impeded in its motion, while the northern part still rushes on with its full speed. The consequence is that the crest of the wave, instead of running parallel to the shore, *i.e.*, about N by W., becomes oblique to it and runs N.E. The obliquity of the waves becomes greater and greater to the south, till finally, on this particular day, at the pier, the crests were at right angles to the shore and the waves ran from N. to S. This is shown diagrammatically in fig. 1.

The case is the same at the south end of the bank, as observed on the 13th. There, however, it is the northern part that reaches the mudbank first. Consequently, the waves become oblique to the shore in the other direction, and run up the coast from south to north. The phenomenon is not so clearly marked as at the north end of the bank.

On the 13th the part of the bank that appeared above the sea had reached a point about a quarter of a mile south of the pier. The waves came in diagonally at the pier, and about a quarter of a mile south ran from N. to S. along the shore.

Except for this slow movement to the south, there was no change of importance till about the 15th. On the evening of the 14th, the backwater, which had been slowly rising, stood 6 inches higher than on the evening of the 4th.

On the 15th a strip of shore close to the sea had subsided some two or three feet. The width of the strip was about 20 yards and its length about 300. The point of maximum subsidence was a little north of the pier; and from this point to the north and south, the amount of the subsidence gradually decreased till at a distance of 100—200 yards from the central point all trace of it had disappeared.

Further north, however, a semi-circular area (the diameter being the actual sea-border) had begun to fall. Instead of subsiding in one piece, this area had sunk in little steps, so that there were a number of little terraces rising one above another from the sea towards the east. The height of the terraces was only a few inches.

At the north end of the semi-circular area, just within the sea, a heap of mud rose above the waves. This heap was surrounded bv a channel or moat, and had the appearance of having been forced up through a hole at the bottom of a crateriform basin. The mud rose in a sort of column to a height of two or three feet above the level of the sand. It was very soft, but so tenacious that it was very little affected by the waves which washed over it.

North of this point there were no signs of disturbance of any kind. But all along the seaward edge of the subsided areas there were a number of basin-shaped holes in the sand, about four or five feet across and three or four feet deep.

On the 16th, the subsidence at the pier had increased, and just within the sea, a long ridge of mud had risen above the waves. This ridge extended, with a few interruptions, to the mud heap observed the day before.

Some of the crateriform holes had become partially filled up with sand. The moat surrounding the mud heap of yesterday was also filled up. It appeared that the column of mud rising in its centre had gradually collapsed. Probably owing to the pressure of mud above, that at the base had begun to flow outwards. By sounding with a stick, I found that the section across the heap was as in fig. 2.

It was impossible on this day, owing to the treacherous nature of the mud, to cross to the seaward side of the line. But on the 17th enough sand had been thrown on the lower parts of the ridge to form a tolerably coherent layer. It was then possible to cross at some points, and I was able to sound the mud heap right across, the result being shown in the figure. The mud fills a basin-shaped hole, the seaward side of which is steeper than the landward side. In the middle I could not reach the bottom of the mud.

A section across the long continuous ridge of mud further south, was nearly the same as fig. 2, but it was there impossible to get to the seaward side.

It is clear, then, that the mud is forced up from below through the sand. As it rises, the sand sinks in round the hole or cleft through which the mud is forced and a basin or trough is formed which the mud afterwards fills.

As soon as the ridge of mud rose above the waves, rounded masses of mud were thrown up on the beach. These were, no doubt, torn off from the mudheaps and rolled about in the waves.

On the 18th and 19th the water in the backwater had risen to the greatest height at which it stood during my stay at Alleppy. No further subsidence took place and the backwater now began to fall slowly.

After this date there was no change in the mudbank till my departure on the 24th; but a few more points remain to be noticed.

The mud thrown up in the manner described is precisely like that found by sounding at considerable depths. It is greenish in colour, very oily-looking, and very tenacious. There is no visible foreign matter mixed with it. But where the water is smoothest and muddiest (at this time, about a quarter of a mile south of the pier), it is full of blackened twigs, &c.; and palm tree roots and pieces of wood are thrown up in quantities. At first sight it appears as if these came out of the mud of the bank. It is more probable, however, that they have been brought down the coast by the current which runs from north to south, and have naturally been collected in such a piece of smooth water as this, just as, in a rapid river, twigs and straws collect behind any projecting point that gives them shelter.

Moreover, it has been already mentioned that the waves approaching the mudbank converge towards this point, and sweep along the shore from the north and the south.

Many of the pieces of wood are rounded and appear waterworn, and they are often bored by *Pholas*. It may be remarked, too, that large numbers of sea-shells are thrown up at the mudbank, and not elsewhere; and that more sand collects along the edge of the smooth-water tract than where there is a heavy surf.[1]

The smooth-water tract is in fact a sort of refuge for everything thrown into the sea anywhere within a reasonable distance; and the presence of vegetable matter, even green and fresh, in the mud volcanoes observed by Mr. Crawford,[2] is perhaps due to this.

On the 21st the smooth water was more extensive than before, and the whole area of the water was variegated with broad shining streaks. On rowing up to these and examining them, I found that the water of the streaks was much less rippled than elsewhere, and was covered by a thin film, most clearly visible with the light of the sky reflected at a particular angle. The film was too thin to be collected, but was probably oil, and certainly had a smoothing effect on the smaller waves. There were several of these broad patches of film-covered water, and they extended some miles out to sea.

Narrakal.

At Narrakal, on the 2nd June, the mudbank was heaped against the shore and a very large area was above sea-level, so that a channel had to be opened to enable boats to reach the sea. Owing

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[1] When the Alleppy pier was built, the mudbank lay far to the south. The shore at Alleppy was then narrow, and the pier stretched well out to sea. Since the new mudbank formed near the pier, sand has collected, until now the sea reaches only the extreme end of the pier.

[2] Mr. Crawford (see Records, vol. xvii, p. 18) speaks of the bursting of the cone of mud, and the throwing up of boulders of mud and vegetable debris. I did not see any cone burst, and the boulder-like lumps of mud and debris on the shore were simply thrown up by the sea.

None of the outbursts in the bed of the roads, which seem to be more striking than those on the sea-border, occurred during my stay.

to the liquidity of the mud the channel was constantly filling up; but it was possible to row a light boat over the mud even where no water appeared.

The sea was much smoother than at Alleppy, and the smooth water extended some distance south of the pier. I observed several of the shining streaks afterwards noticed at Alleppy, but, probably owing to the nature of the light, could only find a film at one or two places. Wherever the water shone, however, the ripples were much smoother than elsewhere.

On the 25th I paid another visit and found the bank and smooth water in nearly the same condition as before. But on going to the edge of the smooth water I found that the rougher water was blue and the smoother muddy in colour. On the smoother water was a film as at Alleppy, and its edge was marked by a line of bubbles and foam. The crests of the waves broke slightly as they entered the muddy water.

The boundary between the blue and muddy water was so well defined that sometimes on one side of the boat the water was deep blue and on the other a reddish-grey. Within the blue water, however, were some muddy-coloured streaks as if the edge of the muddy water had been, so to speak, frayed out in places.

The only way to account for so sharp a boundary seems to be to suppose a current of clear water to run in a south-easterly direction along the outward edge of the mudbank, and to strike the shore some distance south of Narrakal, where the muddy water now ends.

That such a current does exist is well known, and it is to it that the heaping up of the mudbank at the pier is due. Narrakal lies in a shallow bay protected from this current by the slight projection of the shore to the north. The current sweeps by this projection and strikes the shore south of the pier. The greater part of the mud collects in the protected bay.

During heavy south-west monsoons, however, I was informed on the spot, the mud is swept out of the bay (which is quite open to the south-west) and does not begin to collect again until the southerly current recommences.

From the structure of the mud heaps at Alleppy, as already described, it appears that they have been formed by the forcing up of mud from below. There must therefore be a stratum of similar mud at a certain depth below the sand.

It was not until the ground had become thoroughly soaked (as shown by the rising of the water in the wells) and the backwaters had risen slightly, that the eruptions of mud took place.

All this is simply confirmatory of the observations of Messrs. Rohde and Crawford. They have shown that when the backwaters rise, the extent of the smooth-water tract increases, and mud volcanoes burst in the sea. Borings made at various places have reached mud at depths varying from 20 to 66 feet. Between the sand and the mud Mr. Crawford found a crust of chocolate-coloured sandstone.

Mr. Rohde informed me that in making the pier, the screw-piles went in for some distance without difficulty. They then met with considerable resistance, but, this once overcome, they went in easily for the rest of the way. The outermost pile, however, went in from the very first with great, in fact too much, ease. If we supposed the piles to pass through the same beds as were met with in Mr. Crawford's boring, the peculiar behaviour of the screws would be explained. They first passed through sand, then "chocolate-coloured sandstone," and lastly mud. The outermost pier entered the mud at once.

It may be assumed therefore that under the sand of Alleppy is a layer of mud which crops out under the sea. When the backwaters rise to any height, the pressure forces this mud out under the sea and forms the mudbank.

This is, I believe, the theory of Mr. Rohde; but that this mud is the backwater mud is very doubtful. There is not the least resemblance between the two. The mud of the bank is greenish in colour, oily, very tenacious, and owing to its fineness very miscible with water.[1] It is a very fine clay, and of ordinary clays, is more like the under-clay of a coal-seam than any other. The mud of the backwater, on the other hand, is full of vegetable debris, black, lumpy, and contains a high percentage of carbon. It will not mix well with water, and is hardly a true mud.

I am inclined to think that the stratum of oily mud will be found at some depth below the backwater deposits, and that, in fact, it was the silt carried by the rivers into the sea when the coast-line was further east than it is at present, before the sand-bars cutting off the backwaters from the sea began to be formed.

According to the observations of Messrs. Crawford and Rohde, carried on through a long series of years, the mudbank is formed at intervals at Alleppy, and is then gradually washed southwards by the littoral current, being slowly dissipated by the waves at the same time. Usually, before the old bank has quite disappeared, a new one starts at Alleppy.

This year, for example, at Totapallicherra, about 13 miles south of Alleppy, there were the remains of an older bank, which had travelled southwards from Alleppy. I found it fairly well marked; but only in one point was there any trace of it visible above the sea.

As the bank is always formed at Alleppy, we may assume that the outcrop of the oily mud stratum lies there, and that the bed thins out to north and south.

A small mudbank, in all respects similar to that at Alleppy, occurs at Calicut; and in boring for foundations for the bridge over the Kallai river, a layer of oily shale or mud was passed through. This stratum thinned out to north and south, as was proved by other borings. The mud was in character very like that of the Alleppy and Narrakal banks. I have not the full details of the borings with me, but the shale was found in association with beds containing shells and fish-bones. It was obviously laid down by the river when the current at that point was slow.

No connection has been proved to exist between this bed and the Calicut mudbank; but the presence of such beds among the river deposits of the West Coast at least suggests that they may sometimes crop out under the sea; and if there were sufficient pressure during the monsoon on their inland portions, the mud would naturally be squeezed out at its outcrop and would form a mudbank.

Owing to the peculiarly fine nature of the mud it is stirred up by the waves, and in that condition would easily be carried south by the littoral current. It is hardly necessary to repeat any of the observations made showing the liquidity of the mud

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[1] It seems to take some time for this mud to become thoroughly mixed with water; but when once mixed it will remain so for a long time.

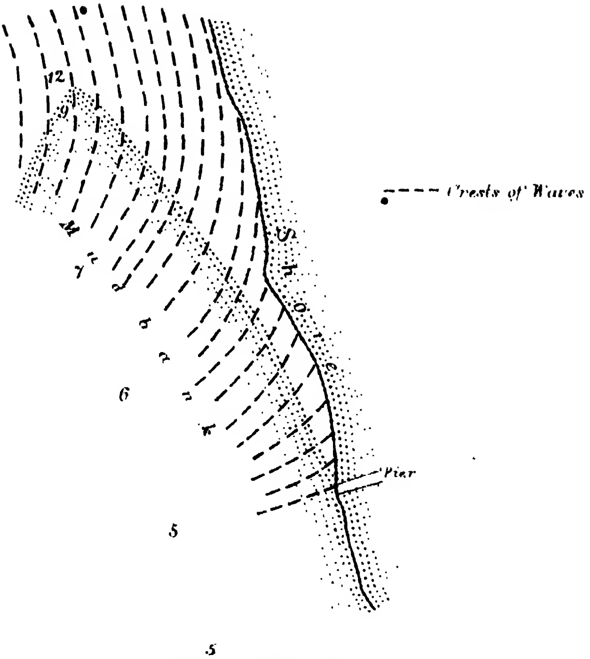

Fig. 1. N. end of Alleppy Mudbank

1 in = 400 yds (Soundings in feet)

Fig. 2. Section of Mud Eruption at Alleppy

when well mixed with water; but an ordinary lead will frequently sink four or five feet into the mud.

The chief point, then, in which I differ from previous observers, is in considering that the Alleppy bank is formed, not from the backwater mud, but from an older river deposit, found only at particular points along the coast. This would explain its non-appearance at other points where the conditions seem equally favourable. With regard to the existence of actual subterranean channels, it may well be doubted whether any could exist in such unstable deposits as are found here.

The Narrakal mudbank is very probably, to a large extent, formed of the silt carried down by the Cranganore river. It does not appear to be very much affected by the rise of the backwaters. It is, in fact, very much what the Alleppy mudbank must have been before the greater part of it was covered up by more recent deposits.

It has already been shown how the Narrakal mud collects in an area sheltered from the ordinary littoral current, and is occasionally partly dissipated when the monsoon current sets in.

The next point to be considered is the manner in which the mud exercises its peculiar smoothing power on the waves.

The mud, as has already been mentioned, is very oily in appearance; and it has been shown by Dr. King to contain a certain amount of oil. I have myself observed a film of what I supposed to be oil, on the surface of the smooth water; and found that where this film existed, the water was smoother than elsewhere. But it did not appear as if the whole effect of the bank could be due to this oil. There was no sharp line between the rough and the smooth water, except at the north and south ends of the banks. As a rule, the waves simply became smaller and smaller as they neared the shore, and at the same time the period of vibration seemed to become longer and longer.

From the manner in which the waves approach the shore, as observed on the 7th and following days, it can be shown that their velocity over the mudbank is less than their velocity over the ordinary sandy bottom. This is easily explained when we remember that over the bank the water. especially the deeper water, is mixed with mud, and this mixture is heavier than pure sea-water; and that the velocity of a vibration varies, when other things remain the same, inversely as the square root of the density of the medium through which it is propagated.

It is to the same cause that we must attribute the decrease in amplitude or size of the wave. As there is more mud mixed with the water at a little depth than there is at the surface, the lower part of the wave is retarded most, and hence the upper, or visible part of the wave, sometimes breaks when it reaches the bank. But if the retardation is more gradual, as would be the case when the bank is first encountered at a great depth, there is no surf. but the wave gradually becomes smaller and smaller.

It is on account of this that the smooth-water tract is defined at its northern and southern borders by a line of breakers, while straight out to sea there is no distinct boundary. At the north end the wave does not meet the bank till it reaches a depth of less than two fathoms; while off a point a little south of the pier, the waves are over mud at a depth of 4½ fathoms, or even more.

GEOLOGICAL SURVEY OF INDIA DEPARTMENT.

TRI-MONTHLY NOTES.

1. ENDING FEBRUARY 1ST, 1890.

Director's Office, Calcutta, February 1890.

The staff of the Survey is at present disposed in the following parties:—

Madras Party.—R. B. FOOTE, F.G.S., Senior Superintendent, Bellary District.
Burma Party.—THEO. W. HUGHES HUGHES, A.R.S.M., Superintendent.
TOM D. LATOUCHE, B.A., 2nd Grade Deputy Superintendent.
FRITZ NOETLING, Ph.D., Palæontologist.

Dr. Noetling left Head Quarters for Rangoon in January, and is placed under the immediate orders of the Chief Commissioner for exploration in Upper Burma.

Baluchistan Party.—R. D. OLDHAM, A.R.S.M., 1st Grade Deputy Superintendent.
Sub-Assistant Kishen Singh.
Sub-Assistant Hira Lal.

Mr. Lake having broken down under sun-exposure was detached from this party in November last and recalled to Head Quarters.

Salt Range Party.—C. S. MIDDLEMISS, B.A., 2nd Grade Deputy Superintendent.
P. N. DATTA, B.Sc., Assistant Superintendent.

Darjiling and Sikkim.—P. N. BOSE, B.Sc., 2nd Grade Deputy Superintendent.
Head Quarters, Calcutta.—The Director; and Officer in charge of Museum and Laboratory.

Mr. Lake has been placed in temporary charge of the Museum and Laboratory, *vice* Mr. E. J. Jones, deceased.

List of Reports and Papers sent in to Office for publication or record during November, December 1889, and February 1890.

Author.	Subject.	Disposal.
R. LYDEKKER, Harpenden, Herts.	Notes on vertebrate remains from the Nagpore District.	Appears in the Records, Geological Survey of India, Vol. XXIII, part 1.
Ditto	On the Pectoral and Pelvic girdles and Skull of the Indian Dicynodonts.	Ditto ditto.

List of Reports and Papers sent in to Office for publication or record during November, December 1889, and January 1890—continued.

Author.	Subject.	Disposal.
DR. W. WAAGEN, Prague .	Notes on the Bivalves of the Olive Group, Salt-Range.	Appears in the Records, Geological Survey of India, Vol. XXIII, part 1.
PHILIP LAKE . . .	Notes on the Mud-banks of the Travancore coast.	Ditto ditto.
C. S. MIDDLEMISS . .	Crystalline and Metamorphic Rocks of the Lower Himalaya.	Ditto ditto.
TOM. D. LATOUCHE . .	Report on the Lakadong Coal-field	Ditto ditto.
" . .	The Sapphire Mines of Kashmir .	Will be published later on.
DR. NOETLING . . .	Notes on the Sonapet gold-field .	Ditto ditto.
W. THEOBALD, Budleigh, Salterton.	Index to first twenty volumes of the Memoirs, Geological Survey of India.	Ditto ditto.
F. R. MALLET, LONDON .	Index to his papers in first twenty volumes of the Records, Geological Survey of India.	Ditto ditto.
" .	Index to his papers in the first twenty volumes of the Memoirs, Geological Survey of India.	Ditto ditto.
R. BRUCE FOOTE . .	Index to his papers in the first twenty volumes of the Memoirs, Geological Survey of India.	Ditto ditto.
MANAGING AGENT, MESSRS. INGLIS & Co., Sylhet.	Remarks and additions to Provisional Index of Local Distribution of important Minerals, &c., in the Indian Empire.	Recorded with thanks.

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of November, December 1889, and January 1890.

Substance.	For whom.	Result.						
Coal from the Makum Collieries, Dibrugarh, Assam.	J. HAMPTON, Steamer Rajput, Mail Service, Dhubri, through T. D. LATOUCHE, Geological Survey of India.		A. Bright specimen.	B. Dull specimen.				
		Moisture	2·56	1·88				
		Volatile matter	36·44	38 00				
		Fixed carbon	59·80	51·92				
		Ash	1·20	8·20				
		TOTAL	100·00	100·00				
			Cakes very strongly, ash, dark red.	Cakes strongly, ash, dark red.				
6 Samples of coal, from Darjeeling.	P. N. Bose, Geological Survey of India.		DAMUDAS.					TERTIARY.
			Ramthi Lake (east side).	2. Ramthi Lake (west side) Lower seam.	6. The Ramthi (west of the Lake) Lower seam.	7. The Lissoo Nadi, Lower outcrop.	9. The Lissoo Nadi, Lowest outcrop.	5. The Jeet, close to the Terai.
		Moisture	·80	·80	1·60	4·72	3·28	17·52
		Volatile matter	3·68	7·88	10·40	22·16	20·60	31·88
		Fixed carbon	52·32	58·12	61·76	60·24	60·12	49·28
		Ash	43·20	33·20	26·24	12·88	16·00	1·32
		TOTAL	100·00	100·00	100·00	100·00	100·00	100·00
		Colour of ash	Dark brown.	Grey.	Light red.	Reddish-grey.	Reddish-grey.	Pale buff.
			Does not cake.			Sinters slightly.		

Mineral sent for determination.	Douglas Betts, Jaraikola P. O., Saranda, *viâ* Chybassa, Singbhum.	Limonite in cubic crystals, pseudomorphous after pyrite.						
Coal from the Lissoo Valley	P. N. Bose, Geological Survey of India.		No. 10. Pit No. 1.	No. 11. Pit No. 2.	No. 12. Pit No. 3.	No. 13. Pit No. 4.		
			%	%	%	%		
		Ash	10·64	8·88	16·12	30·80		
		Colour of ash	Light grey.	Pale red.	Grey.	Buff.		
			Does not cake.					
Coal from the Churanttie Valley.	" "		14. 20 feet seam.	15. 20 feet seam.	16. 20 feet seam.	17. Close to 20 feet seam.	18.	19.
		Volatile matter including moisture	20·80	21·48	17·20	10·28	5·76	1·28
		Fixed carbon	57·92	56·52	63·28	33 08	69·84	27·84
		Ash	21·28	22·00	19·52	56·64	24·40	70·88
		TOTAL	100·00	100·00	100·00	100·00	100·00	100·00
		Colour of ash	Dark red.	Dark red.	Dark red.	Grey.	Dark brown.	Pale reddish grey.
			Cakes but not very strongly.	Sinters slightly.	Cakes but not very strongly.	Cakes but not very strongly.	Does not cake.	Does not cake.

List of Assays and Examinations made in the Laboratory, Geological Survey of India, during the months of November, December 1889, and January 1890—continued.

<table>
<tr><th>Substance.</th><th>For whom.</th><th>Result.</th></tr>
<tr><td>Laterite from Orissa, Bombay, and Burmah.</td><td>GOVERNMENT OF INDIA .</td><td>Determination of weight of laterite per cubic foot.
<table>
<tr><th>Locality.</th><th>Volume (including air contents of the vernicular tubes).</th><th>Weight.</th><th>Sp. Gr.</th><th>Weight per cubic foot.</th></tr>
<tr><td>Chowdwar, Orissa . . .</td><td>(8 in.)^3 = ·2963 c.ft.</td><td>43 lbs.</td><td>...</td><td>145 lbs.</td></tr>
<tr><td>Pulla Tanghy ,, . . .</td><td>(8¼ in.)^3 = ·3249 ,,</td><td>43 ,,</td><td>...</td><td>132 ,,</td></tr>
<tr><td>$\frac{1}{307}$ Sawantwarree . . .</td><td>72 c.c.</td><td>162·5 grms.</td><td>2·3</td><td>143 ,,</td></tr>
<tr><td>$\frac{1}{313}$ Kulladghi . . . .</td><td>258 ,,</td><td>663·3 ,,</td><td>2·6</td><td>162 ,,</td></tr>
<tr><td>$\frac{1}{318}$ Prome . . . .</td><td>181 ,,</td><td>418·9 ,,</td><td>2·3</td><td>143 ,,</td></tr>
</table>
Mean weight per cubic foot = 145 lbs.</td></tr>
<tr><td>Calcite from Hazaribagh</td><td>B. L. FRIZONI, Hazaribagh .</td><td>The calcite is fairly pure, containing:—
Insoluble matter (silica mainly) . . . . 1·24 p.c.
Oxide of iron and alumina . . . . ·06 ,,
Total impurities . 1·30 ,,</td></tr>
<tr><td>Claystone from the Kharakpur Hills.</td><td>C. T. AMBLER, Monghyr .</td><td>Contains:—$\left.\begin{array}{l}SiO_2\\Al_2O_3\end{array}\right\}$ in large quantities.
Fe, trace.
CaO, in small quantity.
MgO, trace.
SO_4, trace.
H_2O, in considerable quantity.
=silicate of alumina; or altered clay-stone.</td></tr>
</table>

<table>
<tr><td>Coal from Baluchistan .</td><td>R. D. OLDHAM, Geological Survey of India.</td><td>
<table>
<tr><th></th><th>Deep workings of the Khost colliery. Upper part of Ghazij group.</th><th>Sharig Nullah, top of Ghazij group, No. 67 of Blanford's section. Mem. xx., 193.</th><th>12 miles S. by W. of Harnai Railway Station. Ghazij group near top. Sample No. 1.</th><th>2 miles S. by W. of Harnai Railway Station. Ghazij group, near top. Sample No. 2.</th></tr>
<tr><td>Moisture . . . .</td><td>2·20</td><td>3·56</td><td>8·12</td><td>8·60</td></tr>
<tr><td>Volatile Matter . .</td><td>40·56</td><td>42·60</td><td>37·64</td><td>34·84</td></tr>
<tr><td>Fixed carbon . .</td><td>47·48</td><td>40·12</td><td>51·04</td><td>49·56</td></tr>
<tr><td>Ash . . . .</td><td>9·76</td><td>13·72</td><td>3·20</td><td>7·00</td></tr>
<tr><td>TOTAL .</td><td>100·00</td><td>100·00</td><td>100·00</td><td>100·00</td></tr>
<tr><td>Colour of ash . .</td><td>Grey. Cakes strongly and forms a light tumid coke.</td><td>Grey. Cakes strongly.</td><td>Dark brown. Sinters slightly.</td><td>Dark red. Sinters slightly.</td></tr>
</table>
</td></tr>
<tr><td>Graphite from Upper Burmah.</td><td>GILLANDERS, ARBUTHNOT & Co., Calcutta.</td><td></td></tr>
<tr><td>Graphite from Nepal .</td><td>MARILLIER & EDWARDS .</td><td></td></tr>
<tr><td>Mineral oil said to have been found at Terai in the Sherani Hills, about 15 miles out of British Territory.</td><td>GOVERNMENT OF INDIA .</td><td></td></tr>
<tr><td>Auriferous gravel, from the gravel bed, Koel River, Chota Nagpur.</td><td>MACKILLICAN & Co., Calcutta</td><td></td></tr>
<tr><td>Cupriferous iron pyrites, in quartz-schist.</td><td>A. M. GOW SMITH, 2, Camac Street, Calcutta.</td><td></td></tr>
</table>

Notifications by the Government of India during the months of November and December 1889, and January 1890, published in the "Gazette of India," Part I.—Appointment, Confirmation, Promotion and Retirement.

Department.	Number of order and date.	Name of Officer.	From	To	Nature of Appointment, &c.	With effect from	Remarks.
Revenue and Agricultural Department.	91 C.—I., dated 8th January 1890.	P. Lake .	...	...	Officiating Curator.	4th December 1889.	

Notifications by the Government of India during the months of November and December 1889, and January 1890, published in the "Gazette of India," Part I.—Leave.

Department.	Number of order and date.	Name of Officer.	Nature of Leave.	With effect from	Date of Return.	Remarks.
		None.				

Annual Increments to graded Officers, sanctioned by the Government of India during November and December 1889, and January 1890.

Name of Officer.	From	To	With effect from	Number and date of sanction.	Remarks.
	Rs.	Rs.			
F. Noetling . .	540	580	1st October 1889.	$\frac{55C.}{S.}$, dated 21st December 1889.	
C. S. Middlemiss .	500	540	1st November 1889.	$\frac{615}{13\text{-}13}$ S., dated 14th November 1889.	

Postal and Telegraphic Addresses of Officers.

Name of Officer.	Postal Address.	Nearest Telegraph Office.
R. BRUCE FOOTE	Harpanahalli (Bellary) .	Harihar.
T. W. H. HUGHES . . .	Mergui (Burma) . .	Tavoy.
C. L. GRIESBACH . . .	Calcutta	Park Street, Calcutta.
R. D. OLDHAM	Sibi (Baluchistan) . .	Sibi.
P. N. BOSE	Pillan's Hat . . .	Siliguri.
T. H. D. LATOUCHE . . .	Chin-Lushai Expedition, Lushai Column.	Chin-Lushai Expedition, Lushai Column.
C. S. MIDDLEMISS . . .	Khewra (Jhelum) . .	Khewra.
P. LAKE	Calcutta	Park Street, Calcutta.
P. N. DATTA	Khewra (Jhelum) . .	Khewra.
F. NOETLING	Yenangyoung . . .	Yenangyoung.
KISHEN SING	Sibi (Baluchistan) . .	Sibi.
HIRA LAL	Ditto . .	Do.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 2.] 1890. **[May.**

Special report *on the* most favourable sites *for* Petroleum Explorations *in the* Harnai District, Baluchistan, by R. D. OLDHAM, A.R.S.M., F.G.S., *Deputy Superintendent, Geological Survey of India.* (With a plan.)

A general description of the mode of occurrence of the petroleum and my reasons for believing that it exists in workable quantities having been given in a separate report,[1] I shall confine myself to a detail of the most promising localities at which to start boring operations.

The anticlinal which ends near Seni village may be dismissed at once; the ground round its termination is very broken, it is very much hidden by recent gravels, and the few exposures seen have all high dips—a combination of drawbacks which precludes its being adopted as a favourable locality to start exploratory operations.

The anticlinal of the Galusha Hill, which terminates near Spintangi, is the most accessible and contains very conspicuous shows, but the dip is nearly every where high, and, what is worse, increases as the boundary of the limestone is left. The one exception to this is at the north-western corner of the hill where the dip is only 20°, and a mile off to the north-west there is an exposure of shales dipping north by west at an average of 15°. There is an extensive plain in this neighbourhood, in the angle formed by the junction of the Kuriak and Dadar streams which is nearly all under cultivation, partly irrigated and partly dependent on rainfall. Were borings established here they would have to be put down 1,000 feet or more according to the situation, and if a number were put down, compensation would have to be paid to the proprietors of the land which would probably counterbalance the advantage of proximity to the line of railway. The locality here referred to is marked B on the accompanying tracing.

Slightly less accessible, though in other respects preferable, is the termination of the Pír Kóh anticlinal. The oil-shows are in one respect better than at Spintangi, for, besides occurring as inclusions in veins of calcite, it is found lining close fissures

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[1] Will appear in Pt. 3 of the Records.

in the limestone, not merely the principal joint planes, but along fissures so close that they are only revealed when the limestone is broken up with a heavy hammer. This shows that the oil must have permeated the rock under pressure and was not merely washed up in a current of hot water.

The most obvious plan would be to bore on the continuation of the crest of this anticlinal: but, in the first place, there is no certainty that it continues as an anticlinal for any distance beyond the termination of the hill, and, in the second place, it would involve boring on a plateau to which water would have to be pumped or carried a height of nearly 100 feet. Beyond the somewhat problematic advantage of possibly boring on the crest of the anticlinal where this itself probably slopes at an angle of 20° or more, there is nothing to be gained here over the level ground near the village of Pír. True it is on the flank of an anticlinal, but the oil-shows along this very flank show that oil can rise under pressure in such a situation, and the dip is moderate, probably under and certainly not much over 20°.

The locality is easy of access; heavy machinery could be brought up with but small expenditure on road-making; an abundant supply of water could be brought in by gravitation from the neighbouring stream, and there is no cultivation to injure. Should oil be found in workable quantities, a branch line of three miles long could be made at a small cost, and this line would traverse a considerable area of low and rolling dips, over which the borings could be extended with a fair prospect of success.

If it is determined to bore here,—the locality is marked A on the tracing,—the boring should be put down at such a distance from the boundary as to strike the limestone at some depth below the surface, say, not less than 500 or 700 feet, and so strike what oil there may be under pressure.

There are some indications of an anticlinal near the line of railway between Sunari and Spintangi, but it is somewhat doubtful, and there is a depth of at least 2,000 feet of shales over the Dunghan limestone.

The most favourable locality in many respects, though the least accessible, is that marked C in the Kipar Valley. There is here a very well defined anticlinal fold; the rocks at the surface are the Ghazij shales, and the Dunghan limestone, to which we must look as a reservoir, would be struck at a depth of not less than 1,500 to 2,000 feet. The conditions for accumulation of oil under pressure are distinctly favourable, as there is a well-marked anticlinal axis, protected by a thick cover of impervious shales.

As regards facility of working, there is a broad plain of about a mile and a half long by three quarters of a mile broad, and other smaller tolerably level pieces of ground. The water-supply I cannot speak of with certainty. At the time of my visit (13th January 1890) there were several pools of water, and in one place a string of these was connected by a small driblet of water flowing over the surface which probably did not represent a tithe of the quantity escaping by percolation. I was informed that these never dried up entirely, and that water could always be obtained by digging in the stream-bed. This statement is probably correct as the pools were full of fish, running up to a quarter of a pound in size, though there are only a few small scattered pools of water between here and Spintangi.

The drawbacks are that it would be impossible to get heavy machinery in

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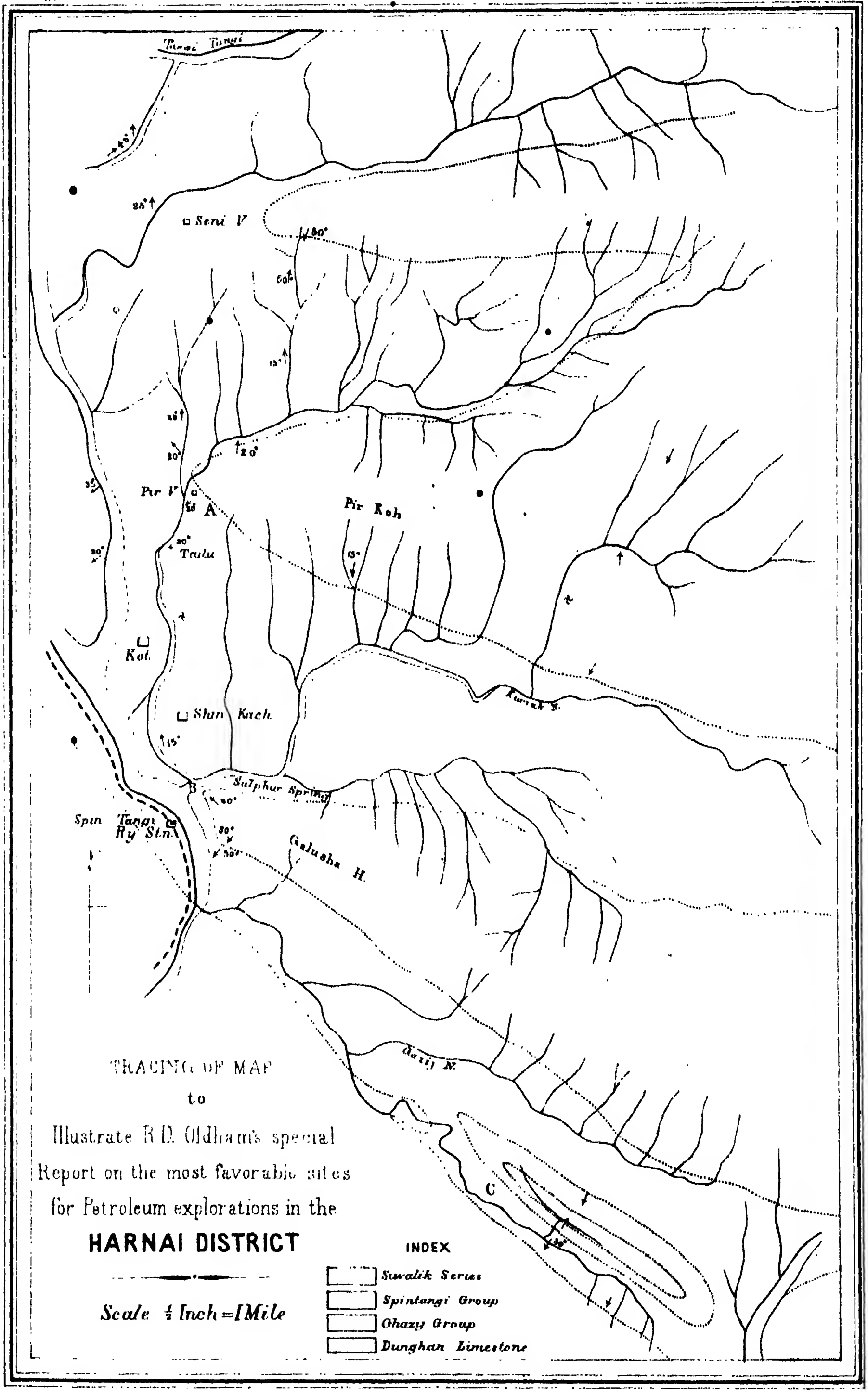

TRACING OF MAP
to
Illustrate R D Oldham's special
Report on the most favorable sites
for Petroleum explorations in the

HARNAI DISTRICT

without some road-making, and a branch line from the railway would be somewhat expensive, as there are two considerable stream-beds to cross and quite half the distance is broken ground involving a quantity of cutting and embanking, heavy gradients, and sharp curves. These are, however, nothing greater than would be encountered by a railway to Khattan, excluding the last twelve miles, and far easier and less expensive than that last twelve miles would be.

To sum up, the advantages and disadvantages of the three localities are as follows:—

A.—Spintangi.

Advantages.—Easy of access and consequently saving of expense in bringing in machinery or taking out oil.

Drawbacks.—Uncertainty as to structure and consequently as to prospect of obtaining oil, and certainty of heavy expenditure in compensation if operations on a large scale are undertaken.

B.—Pir.

Advantages.—Somewhat better *à priori* prospects of success than at Spintangi; only three miles distant from line of railway over an easy country; ample water-supply and room for expansion both at the terminus and along the line of a branch railway.

Drawbacks.—Imperfect exposure of rocks and consequent absence of absolute certainty as to the best sites for boring; not quite so easily accessible as Spintangi.

C.—Kipar Mand.

Advantages.—Certainty of obtaining oil in as great abundance as it can be obtained in this district.

Drawbacks.—Want of accessibility as compared with Spintangi or Pir; possibility of deficient water-supply; uncertainty as to depth at which oil will be struck. Of these the last only is insuperable, and there are prospective advantages to be gained by striking the oil at a great depth.

Taking all things into consideration I am in favour of the second locality, that of Pír, being adopted for the commencement of explorations.

Camp, Sibi, dated the 29th January 1890.

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The Sapphire Mines *of* Kashmir; *by* TOM D. LATOUCHE, B.A., *Deputy Superintendent, Geological Survey of India.* (With three plates.)

The existence of sapphires in considerable quantities in some part of the North-West Himalayas was first brought to light in 1881, or early in 1882, when some were brought into Simla by traders from Lahol, who stated that they had been obtained from a spot among the mountains on the borders of Zanskar, where a landslip had laid bare the rocks beneath the soil, and disclosed the presence of the gems. Various stories are told of the original discovery; according to one of these, which was told me on the spot, a certain shikari, having lost the flint from his gun while out hunting, or, as is the custom of the natives when in want of a light for their pipes, looking for a handy fragment of quartz or other hard rock to strike a light with, picked up a small sapphire, and finding that it answered his purpose better than the ordinary fragments of quartz he was in the habit of using, carried it about with him for some time, and eventually sold it to a Laholi trader, by whom it was taken to Simla, where its value was recognised. Enquiries were then made, which resulted in the discovery of the spot where the shikari had picked up the stone, and for some time, until guards were posted near the locality by the Maharajah of Kashmir, in whose territory it lies, large quantities of the stones were brought to Simla and sold at absurdly low prices, the Laholis only asking about one rupee per seer for them. Another story runs to the effect that a number of traders who had arrived in the Simla bazaar with borax from Rupshu were emptying their baskets in a merchant's shop, when a stone fell out and was thrown by the merchant into the street. The well-known jeweller, Mr. Jacobs, happened to be passing at the time, and, so the story goes, was struck by the stone. Picking it up, perhaps with the intention of returning it, he saw what it was, and on the merchant's claiming it, when he saw that there was something unusual about it, bought it for a small sum. This latter story, if it is to be relied on, would seem to point to the existence of another and as yet unknown locality for the gems, somewhere in Rupshu; otherwise it would be difficult to account for the presence of the sapphire among the borax, which is brought to Simla along a route that does not pass anywhere near the known locality in Padar. Various stories have been circulated of the discovery of sapphires in Kulu and other portions of the North-West Himalayas, but up to the present time none of these have been confirmed.

Early in 1882 a few specimens of the gems were sent down from Simla to the Indian Museum, and examined by Mr. F R. Mallet, who published a full account of their mineralogical and chemical characters in the Records for that year—Vol. XV, page 138. Mr. Mallet also published an account of them, with figures of the crystals, in Part IV of the Manual of the Geology of India, p. 40. In the former paper he says:—"The physical and chemical characters of the specimens show conclusively that they are true sapphires. The specific gravity of the larger piece was found to be 3·959 and of the smaller 3·961. The mineral scratches topaz; is infusible before the blowpipe; and when fused in powder with acid potassium sulphate, and dissolved in water, yields a bulky precipitate of alumina with ammonia."

At the time when these specimens were sent down, considerable doubts existed as to the locality in which they were found. This was partly due to the similarity in the name of the district of Padar in the Chináb Valley, in which they were actually found, with that of the village of Padam[1] in Zanskar, from which district it was at first stated that they had been obtained. This mistake was pointed out by

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[1] In the name Padam the "a" is short, while the first in Pádar is long; the former word is the same that occurs in the Buddhist prayer, "Om mani padme haun," and is said to signify a lotus. The village is so named from being built round the foot of a conical knoll, on which the chief's house stands, thus resembling the petals and central portion of a lotus blossom.

Mr. Lydekker in his memoir on the geology of Kashmir (Memoirs, Geological Survey, Vol. XXII, p. 336). The locality is correctly given in a letter from the Rev. A. W. Heyde, Moravian missionary at Kyelung, printed with Mr. Mallett's paper in the Records above cited, as 2 or 3 *kos* to the east of Machél in Pádar; but the statement of one of his informants, that the place could be most easily reached by way of the Pentse La, one of the passes leading from Kashmir to Zanskar, is incorrect; as a lofty range of mountains extends between the actual locality and that pass.

In the year 1887 the Kashmir Durbar, finding that the revenue from the mines, which had been worked by them with considerable profit since the first discovery, was steadily diminishing, applied to the Government of India for a geologist to examine the mines, and I was deputed to visit and report upon their present condition. I arrived at Srinagar about the middle of August, and obtained as much information as possible about the position of the mines, which I was told were situated near the village of Soomjam on the Bhutna, a tributary of the Chináb entering it from the north-east at Gulabgarh in the district of Pádar. Crossing the Marbal pass, 11,550 feet, at the head of the Kashmir Valley, I reached Kishtwar, near the junction of the Wardwan and Chináb Rivers, both of which had to be crossed by *jhulas*, or rope bridges, in 6 days. Thence a somewhat difficult path led up the left bank of the Chináb to Gulabgarh. The river runs through an exceedingly deep and narrow gorge, and the path generally keeps at a considerable height above it, but the numerous side streams, which also run in deep gorges, necessitate a descent and ascent of two or three thousand feet in several places, so that the marches are very trying: the path is, however, practicable for unladen ponies. This portion of the journey took 5 days to accomplish, though the distance from Kishtwar in a direct line is only 24 miles. At Gulabgarh the valley opens out considerably and is well cultivated: here the Chináb is again crossed by a long and somewhat shaky *jhula* close to an old fort which stands at the junction of the Bhutna with the larger river. From this point, which is about 6,000 feet above sea-level, the rise up the valley of the Bhutna is considerable, about 250 feet per mile, but the valley is more open, and the path keeps near the bank of the river, so that travelling is much easier. Soomjam, the highest village on the southern side of the lofty range dividing Zanskar from the Chináb Valley, is reached in 2 marches, or 13 in all from Srinagar; this village lies at an altitude of about 11,000 feet in Latitude 33° 25′ 30″ N. and Longitude 76° 28′ 10″ E., at the lower end of a broad level plain, about 5 miles long and ½ mile broad. This was formerly occupied by an extension of the glaciers which now descend only as far as its upper end from the passes leading into Zanskar, a large moraine stretching from side to side of the valley immediately above Soomjam, and the polished surfaces of the cliffs on either side, indicating their former extent. A general extension of the glaciers in former times over the whole of this region is shown by the occurrence, near the head of each of the streams draining this range of mountains, of a similar more or less level and open plain, near the lower ends of which are generally found the remains of an ancient moraine. But the difference in altitude between these old moraines and those now forming is not so great as one would expect, considering that in other parts of the Himalayas they are found as much as 5,000 feet below the present limits of the glaciers. This may perhaps be accounted for by supposing that during glacial times this portion of the hills stood at a lower elevation than at present, and has undergone a considerable upheaval since that period.

A steep climb of about 2,500 feet to the W. N. W. from Soomjam brings one to the lower end of a small triangular valley, formed by a bifurcation of one of the spurs that run down from the lofty peaks to the north, and in this the sapphire mines, or rather diggings, are situated. This valley is shut in on the north and west by steep cliffs rising to some 3,000 feet above it and is open to the south and east, whence there is a magnificent view of the glaciers and snowy peaks surrounding the head of the Bhutna and its tributaries. The trigonometrical survey station of Ganar, 14,210 feet, lies about a mile to the west of the mines, and I found by careful comparison of simultaneous observations made with mercurial barometers that the altitude of my camp, just below the workings, was 13,160 feet. Up to this level the hill-sides are covered with grass and various flowers, a wild onion being very common; but it is just above the limit of the birch, which reaches an altitude of about 12,000 feet on the slopes below. Above this the ground is nearly bare of vegetation, a few grasses, stonecrops, and scanty flowers, among which a kind of musk with a dark bluebell-shaped flower was rather common, being the only plants. When I visited the place in 1888 in the middle of July, snow was lying on the ground close above the camp to a depth of 8 feet, and did not disappear till the end of August, a few small patches lingering on throughout the year. The climate, however, was not severe during the time I was there; between the 17th July and the 23rd September the thermometer did not once fall below freezing point, and snow fell on only three occasions, the 23rd August and 24th and 30th September. The lowest temperature registered was 28° F. on the 27th September and the highest 69·2° F. on the 15th August. At the beginning of October snow began to fall regularly and work had to be given up for the season.

The small upland valley in which the sapphires are found is about 1,000 yards long by 400 yards broad at its lower end; the floor rises at an average angle of about 20° to the north-west, narrowing to a point, and is thickly covered with loose débris fallen from the surrounding cliffs. It is from a narrow strip of this débris, averaging about 100 feet in width, along the northern side of the valley, that the sapphires are at present obtained. They appear to have been originally derived from a spot high up on the cliffs to the north of the valley, near the head of a small ravine which enters it at some distance from the apex (see plan, Pl. III); this accounts for their distribution along only one side of the valley.

The rock of which the cliffs are composed is mainly a coarse schistose gneiss, containing a white felspar and much black mica; portions of it are also crowded with deep red and brown garnets. On the northern side a thick bed of coarsely crystalline siliceous limestone (seen to the right of Pl. I near the top of the cliff) is intercalated with the gneiss. This I traced to the south-east as far as Soomjam and to the north-west for about two miles. The thickness of the bed is not constant, as it increases from about 6 feet near Soomjam to 100 feet or more near the mines, but its upper and lower surfaces appear to be strictly conformable with the foliation planes of the gneiss. Also interbedded with the gneiss are several large masses of a peculiar hornblende-like rock (kupfferite): this is in part a felted mass of fibrous lamellæ, and in part made up of radiating fibrous aggregates several inches in diameter: the colour is generally grey or olive green, with patches of a brighter green. The masses are frequently from 20 to 30 feet thick (one large detached mass, under which the coolies employed at the mines have burrowed holes in which they live, standing out from the hill-side close to my camp, must have been 100 feet thick at least), but die away rapidly in a horizontal direction. Between them and the gneiss is generally found a band, from 1 to 2 feet thick, of a soft rock composed of short acicular fibres, bright green or white in colour, apparently of the same mineral, or in places a band of rock entirely composed of crystals of mica. I have only found this rock in the vicinity of the sapphire mines, but whether its presence is in any way connected with the development of the sapphires I cannot say. I found one specimen in which a crystal of sapphire was imbedded in the kupfferite, but this was the only case I saw of their occurrence in contact. All these rocks have a pretty constant easterly dip of about 40°. Lastly, the gneiss is traversed by numerous dykes of granite occasionally parallel with its foliation, but usually cutting directly across it. This granite is generally very coarse-grained (pegmatite), composed of large crystals of milk-white felspar with much quartz, either clear or milk-white and occasionally pink, and sparsely scattered plates of dark-coloured mica up to an inch or so in diameter. As accessories the granite contains well-developed crystals of black tourmaline, called *coal* by the coolies, sometimes of large size (up to 4 or 5 inches in length), light-green enclase, kyanite, minute red garnets, and finally crystals of corundum or sapphire. These last are associated with a white felspar, apparently a plagioclastic variety, occurring in small grains, which give a porous character to the portions of the rock in which they occur. The sapphire crystals appear to be very local in their development, the only spot where they have hitherto been found *in situ* being near the top of the ridge bounding the northern side of the small valley above mentioned, and about 1,600 feet above it. Here the face of the rock has been laid bare by a landslip, and at first the sapphires were taken out of the granite itself; but when I visited the mines this patch of rock had ceased to yield any for some time, nor did the closest search bring any more to light. On the northern side of the ridge, however, I discovered some large blocks of the granite crowded with crystals of corundum, most of which had a bluish tint; but all my efforts to find the source of these blocks were of no avail, owing to the enormous depth to which the rocks composing this side of the ridge had been weathered,—so much so that it would require a landship to lay the rock sufficiently bare to enable it to be properly searched. I attempted to bring one about by digging deep trenches across the hill-side in which water might collect, but without success.

Although many dykes of granite are seen in other parts of the cliffs surrounding the head of the valley, none of them appear to contain sapphires, and none are found in the débris covering the floor of the valley, except in a narrow strip along its northern edge. In this, crystals and fragments of sapphire and corundum are fairly numerous, especially near the head of the valley; and at the time of my first visit about 100 coolies were employed in searching for them by digging up the surface with small *kodalis* and picking up any sapphires they came across. This was not a very satisfactory method of working the deposit, for the darker coloured and therefore better gems were liable to escape notice, and the upper 6 inches or so were worked over and over again, with very poor results: so I had a simple washing apparatus made of a few planks and set up at a large spring which issued from the hill-side near the camp, and the stuff containing the sapphires carried down to it in baskets. This washing apparatus consisted of a platform about 6 feet square, over which a strong stream of water was kept flowing, which carried away the mud and finer particles, the coarser pebbles and sand being held back by a low edging of upright planks; then when cleaned sufficiently the sand and gravel were thrown into a broad and gently sloping trough, through which a moderate stream of water was kept running, when the sapphires could easily be detected and picked out (Pl. II). Most of the stones obtained in this way were small fragments, some not much larger than a pin's head, and crystals, the great majority shewing very little colour and being of small value as gems. Occasionally, however, a larger stone of good colour would be found; thus the largest obtained in 1887 weighed about 6 oz., and was partly of a very brilliant colour; but in 1888 the largest weighed only 104 grains, and very few were found weighing more than 50 grains. These are not to be compared with those brought down when the mine was first discovered. I was shown some in the treasury at Jammu that measured 5 inches in length by 3 inches in breadth, and though none of these were uniformly coloured, but shaded off into white at either end of the crystal, still some very fine gems might be cut from them.

In order to find out whether or not the deposit was equally productive in every part, I had small pits dug at various points, and the stuff taken out of each of them weighed and then washed separately, afterwards weighing the sapphires obtained. It was found that the yield of sapphires steadily decreased towards the lower end of the deposit; but it so happened that the largest stone obtained was found in the lowest pit of all, which, however, produced only one other fragment of sapphire, weighing ¼ tola. It would probably therefore be worth while to work over the whole of the deposit, which can easily be done by the use of such a washing apparatus as I devised, though, owing to the shortness of the season during which work can be carried on, it will take several years yet to do so. I found also that the productiveness of the deposit decreased rapidly from the surface downwards, so that at a depth of more than 3 feet no sapphires whatever were found.

During the working season of 1888, *i.e.*, from the 17th July to the 29th September, the total quantity of corundum obtained was 1,630 tolas, of which perhaps one fourth would be commercially valuable; but the average weight of the stones, calculated from the results of 25 days' working, during which I counted and weighed each day's production, was not more than 10 grains; and I hardly think that, considering the inaccessible character of the locality, the difficulty of obtaining labour and of preventing smuggling, the yield of sapphires will in the future be very profitable, unless the actual bed in which they occur *in situ* can be again discovered.

Besides the corundum several other minerals, interesting from a scientific point of view, though not commercially valuable, are found in the granite of this region. For a determination of the species of most of these I am indebted to Mr. F. R. Mallet, late of the Geological Survey, who kindly examined them for me. These are the following:—

1. Light-green crystals of tourmaline are found in a granite vein about 1 mile

from the ridge in which the sapphires occur; they are fairly numerous in some parts of the rock, thickly encrusting the surface of large crystals of quartz, or penetrating for some distance into their interior. The crystals are transparent, very thin in proportion to their length, seldom reaching a length of more than two inches, with a breadth of about ⅛ inch, and are very brittle. Their mode of occurrence is exactly similar to that of the rubellite, a pink variety of tourmaline, of Rozena in Moravia (Indian Museum), which is also found in long thin crystals penetrating crystals of quartz.

2. A rare mineral, Cookeite, which is stated by Dana (Manual of Mineralogy, p. 314) to be an alteration product of rubellite, is found enveloping the green tourmaline; a cross section showing a rod of the latter enclosed in a thick walled tube of Cookeite; this is pink or white in colour and occurs in fairly considerable quantities. Mr. Mallet says: "The hardness is about 2·5; lustre pearly on cleavage faces; it exfoliates strongly when heated before the blowpipe, and colours the flame crimson, showing the presence of lithia."

3. Spodumene. A few lilac-coloured crystalline blocks of this mineral, which also contains lithia, were found in a valley to the north of the sapphire mines, between them and the place where the green tourmalines were found: none of these were found *in situ*.

4. A large block of prebnite was also found in the same valley. There can be no doubt, I think, that this and the last mineral were derived from the granite.

5. Traces of copper carbonate were found in some of the granite veins to the west of the sapphire mines, but in very small quantity.

6. Some well-formed hexagonal prisms of beryl were brought to me from near Machél, a village on the Bhutna below Soomjam. On my return from the mines I visited the place, which was about 4 miles to the west of Machél and at an altitude of about 12,000 feet, but I found that the beryls did not occur in any large quantity, and those found were very poor in colour, bluish green shading into white.

7. A few pieces of a dark-blue mineral, lazulite, were brought to me, which were said to have been obtained from an almost inaccessible spot two or three days' journey from Gulabgarh. I was not able to reach the spot by reason of a heavy fall of snow which came on while I was at Gulabgarh.

8. Fairly clear crystals of quartz or rock-crystals are obtained in many places over the whole of this region, but they do not seem to occur in sufficient quantity in any one place to make it worth while to mine for them systematically.

While at the mines I made several excursions into the valleys near, and sent out many intelligent natives to try and discover new localities for sapphires, but, except in one instance, without success. This was close to the Hagshu-lá, one of the passes leading from the Bhutna Valley into Zanskar; and as I crossed this pass on a flying visit which I made to Zanskar during my stay at the mines, I was enabled to investigate the "find." The pass is about 16,600 feet in altitude, and large glaciers descend from it on either side to the north and south. Near the head of that on the southern side, and close to the foot of the final ascent from the glacier to the pass, a large block of granite, lying on the moraine beside the glacier, was pointed out to me, which contained numerous blue hexagonal crystals, and these on investigation turned out to be sapphires. At first I thought that they were merely kyanite, as they appeared to possess the different hardness on two faces of the crystal which is characteristic of that mineral; but Mr. Mallet found that this was really due to a glaze of mica covering the basal cleavage planes which he thinks is caused by a partial alteration of the mineral, and pronounced them to be really sapphire. Some of the crystals were about an inch in diameter, but none of them were of a good colour throughout, the blue shading into a greenish blue in places. It was impossible to discover the source of this block of granite, which was the only one visible, during the short time I was able to stay at the spot, but there can be no doubt that it came from some part of the cliffs surrounding the head of the glacier. The spot where this block was lying is about 15,500 feet above the sea, and it probably came from some point which is much higher, and perhaps inaccessible.

I could obtain no information confirming the statement made in Mr. Heyde's letter, quoted above, that "in the immediate neighbourhood of the spot described" (*i.e.*, Soomjam) "the people know of two others, in one of which the blue stone is found, not below the ground, but in horizontal seams of a large rock, but also, as it appears, surrounded or embedded in that white stuff." This may refer to the lazulite found near Gulabgarh, which is associated with a white schistose mineral. Nor could I get any further information about the locality which in the same letter is said to exist above the monastery at Bardun in Zanskar, and I was not able, from want of time, to pay a visit to Bardun. There seems to be no reason, however, why sapphires should not occur in many other places in this region where the rocks are pierced by granite veins, and other localities may in time be brought to light either by chance, as in the case of the original discovery, or by a closer search than I was able to make.

After I had seen the operations at the sapphire mines fairly commenced and in working order, I paid a visit to Zanskar, whence specimens of certain other minerals besides the sapphire above described had been brought to me, and as the district appears to be one seldom visited by Europeans, some account of my journey may be interesting. Leaving Soomjam about the middle of August, I crossed the main range by the Hagshu-lá 16,600 feet, a pass which is not often used by the natives, though a good deal lower than the Umasi-lá further to the east. Large glaciers descend from either side of the pass, that on the north being the longer, about 16 miles, without counting its numerous tributaries. The glaciers are easily traversed after one has surmounted the mass of moraine matter which entirely covers their lower ends, sometimes for a distance of half a mile or more; above this the surface is generally nearly level, and very free from crevasses, those that do occur being usually narrow and easily jumped across; until the head of the glacier is reached, where there is generally a steep slope rising towards the nevée, and cut up by numerous large transverse crevasses, which occasionally give trouble, but with care they can be avoided, and ropes are never used by the natives while crossing them.

The valley, called the Hagshu Tokpho, leading down from the pass to the north, opens into the wider valley of the Zanskar River, a large tributary of the Indus; here the valley is open and fairly level for a long distance, containing many villages and monasteries, and in parts well cultivated, but almost bare of trees. The only trees of any size that I saw were some small poplars planted near the village of Seni; these I was told had been brought from Ladakh. A shrubby willow is plentiful in the ravines on either side of the main river and along its banks, but all timber for building purposes has to be imported.

To the north of the Zanskar River in this part of its course a considerable change takes place in the aspect of the mountains, corresponding with a change in their geological structure. Those on the south are rugged and precipitous, mainly formed of gneiss, while on the north they are generally smothered in talus to their summits, which gives them a more rounded appearance and renders them easy to climb; the latter are formed of the slaty schists of the Panjal series, a rock which disintegrates rapidly under the action of frost.

I crossed these mountains by a little-used path across the Rulakun-lá, about 17,500 feet—an easy pass and quite practicable for hill ponies; some miles, however, to the north of the pass, near the village of Rulagong, another change takes place in the nature of the country, corresponding again with a change in the rocks. These are massive limestones and slaty rocks of Supra Kuling age, much contorted on a large scale, and through them the streams have cut enormously deep ravines with almost perpendicular sides, recalling, though perhaps on a small scale, the cañons of America. The Zanskar River has also cut a similar gorge through these rocks, where the gorge, 100 feet above the river, is sufficiently narrow to allow of a wooden bridge being thrown across. I was informed that the lumps of native copper, from which Zanskar is said to derive its name, are found in the bed of the river near this bridge, but only in the winter, when the upper waters of the river are frozen, and the bed here is more or less dried up; in September, when I crossed it, the river was in full flood, and it was useless to attempt to search for the copper.

Three days' marching through the gorges north of Rulagong brought me to the village of Linshot, at the foot of a lofty scarp, mainly formed of a black fœtid limestone, the upper beds of the Supra Kuling series. Near this village I discovered several large masses of a similar black limestone crowded with *nummulites*, and traced them up to a peak, called Z^4 on the maps, immediately above the Singhe-lá, 16,601 feet, a pass by which the scarp is crossed, where I found the *nummulites in situ* at an elevation of about 18,500 feet above sea-level. These nummulites were first discovered by Dr. Thomson in 1852 when he crossed Singhe-lá, but subsequently Mr. Lydekker had thrown some doubt on this being the locality in which they were found, as they escaped his notice when he crossed the pass. A description of the locality and the rocks in which the *nummulites* occur will be found in the Records, Geological Survey, Vol. XXI, Pt. IV, p. 160.

The depression which forms the pass itself, as well as another, the Sirsa-lá, of about the same height, several miles to the north, is caused by the intervention of a broad band of shaly rocks between the black limestones on the west and the hard limestones and slates of the lower Supra Kuling series on the east; these latter are sharply contorted on a large scale, the differently-coloured bands of rock rendering the contortions very visible on the precipitous face of the cliffs. Many sections thus exposed recall the familiar examples of rock twisting shown in Heim's plates of the structure of various parts of the Alps.

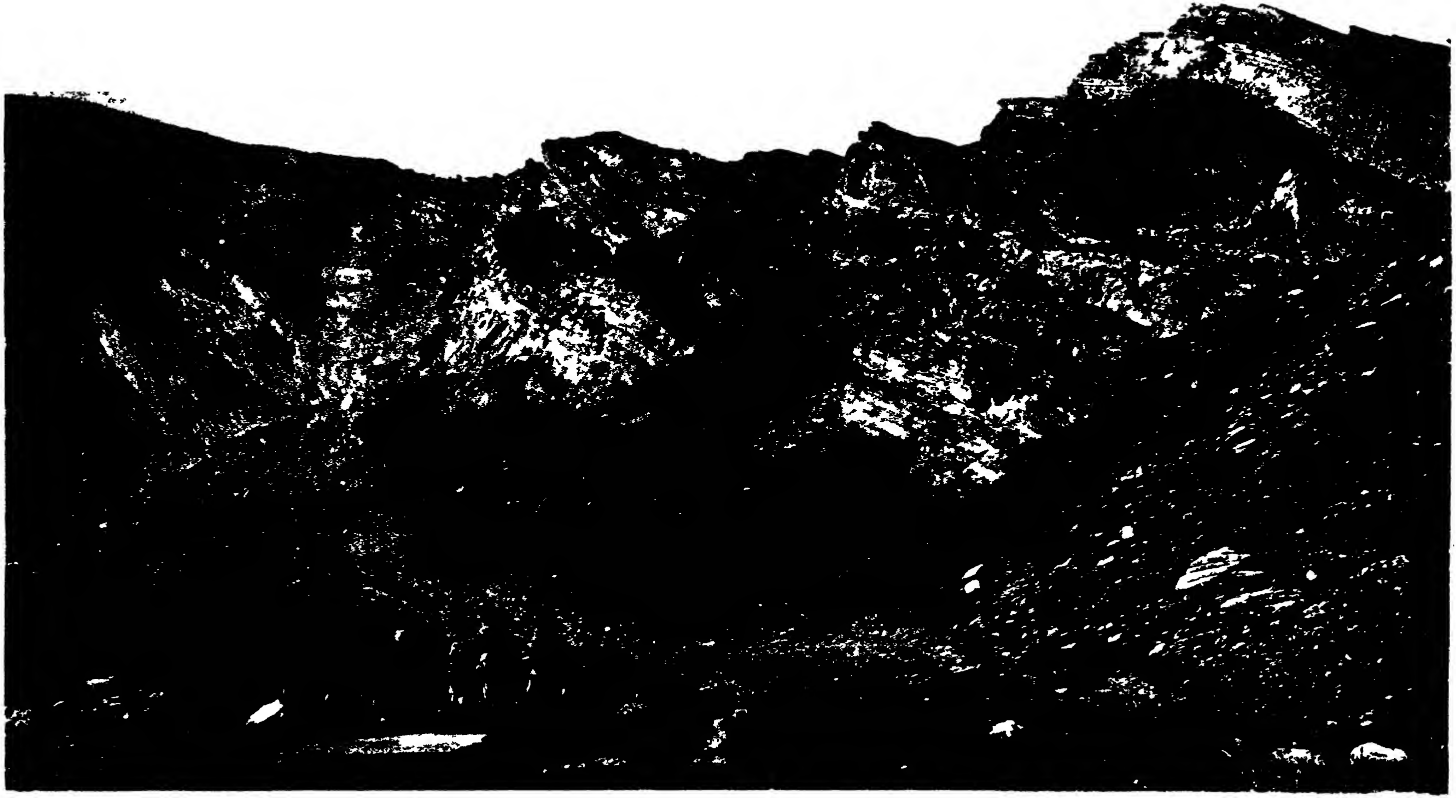
In the valleys to the north and west of the Sirsa-lá are found numerous blocks of a whitish heavy rock, allied to jadeite, called zoisite; it takes a high polish and might be made use of in the same manner as jadeite for ornamental cups, &c. A small quantity is sometimes taken to Lahol by the natives, so they told me, and sold for about R3 per seer. It eventually finds its way to Amritsar, I believe, where it is cut and polished. The Srinagar stone-workers to whom I showed some specimens of it, found that it was too hard for them to work into ornaments. The source of these blocks of zoisite is probably the area of tertiary trap shown in Mr Lydekker's map to the south-west of the Sirsa-lá, and forming the peaks D^{24} and D^{25}, which are drained by the streams to the west of the pass. Numerous blocks of the traps are found with the zoisite, and in many cases the two are intermingled in the same block.

From this point I returned, taking the more frequented route through Yelchung to the Zanskar Valley near the village of Zangla. In many of the ravines through which this route passes earth-pillars are very numerous and often of large size. One group of them is in the Khurna-foo Valley; they are formed from a stiff clay which has apparently been consolidated by the weight of glaciers—a *grund moraine*, in fact,—and this is frequently full of large blocks of rock which are sometimes seen either capping the pillars or sticking out from their sides.

From the Zanskar Valley I returned to Soomjam across the main range by the Umasi-lá 17,369 feet, a pass which, though nearly 1,000 feet higher than the Hagshu-lá, is not so difficult, and is often crossed by ponies, several of which were brought across by my party. The valleys on either side are filled with large glaciers; but these do not present many difficulties. A halt has to be made near the top of the pass at an elevation of about 16,000 feet, and here, as may be imagined, it is bitterly cold; but unless a strong wind is blowing—and this as far as my experience goes is a very rare occurrence at night during August and September,—one can camp out, even at this altitude, without much discomfort.

On my return to the sapphire mines I found the work progressing favourably, though no gems of any remarkable size had been found during my absence. With the end of September the weather began to break, and snow fell for some days, so that work had to be given up for the season; and after weighing and packing up the season's yield of sapphire, which was taken in charge by the Maharaja's officials to be carried direct to Jammu, I set out on my return journey to Kashmir. On the way I visited various localities in which rock-crystal, iron ore, and other minerals were said to exist, but did not find any of them worth the trouble of mining. Among these was a bed of arsenopyrite, a compound of arsenic, sulphur, and iron, which was found near the village of Berali between Gulabgarh and Machél, and at about 3,000 feet above the Bhutna; but the bed seemed to be small in extent. I also paid a visit to the iron-works of Soap in the Kashmir Valley, the ore for which is obtained from a bed of impure calcareous limonite intercalated in the limestones and rocks to the east of Achibal. The bed is only 1 or 2 feet in thickness, and dips at an angle of 35° into the hill, but its outcrop extends for a distance of at least two miles along the hill-side, and there must be sufficient ore here to keep the small native furnaces supplied for many years to come, so long as there is any demand for the iron, but it would certainly not be advisable to start large blast furnaces on the English plan, and moreover the ore seems to be very poor in quality.

So much has been said lately about the great mineral resources of Kashmir, that it may perhaps be well, in conclusion, to say a few words on the subject. In



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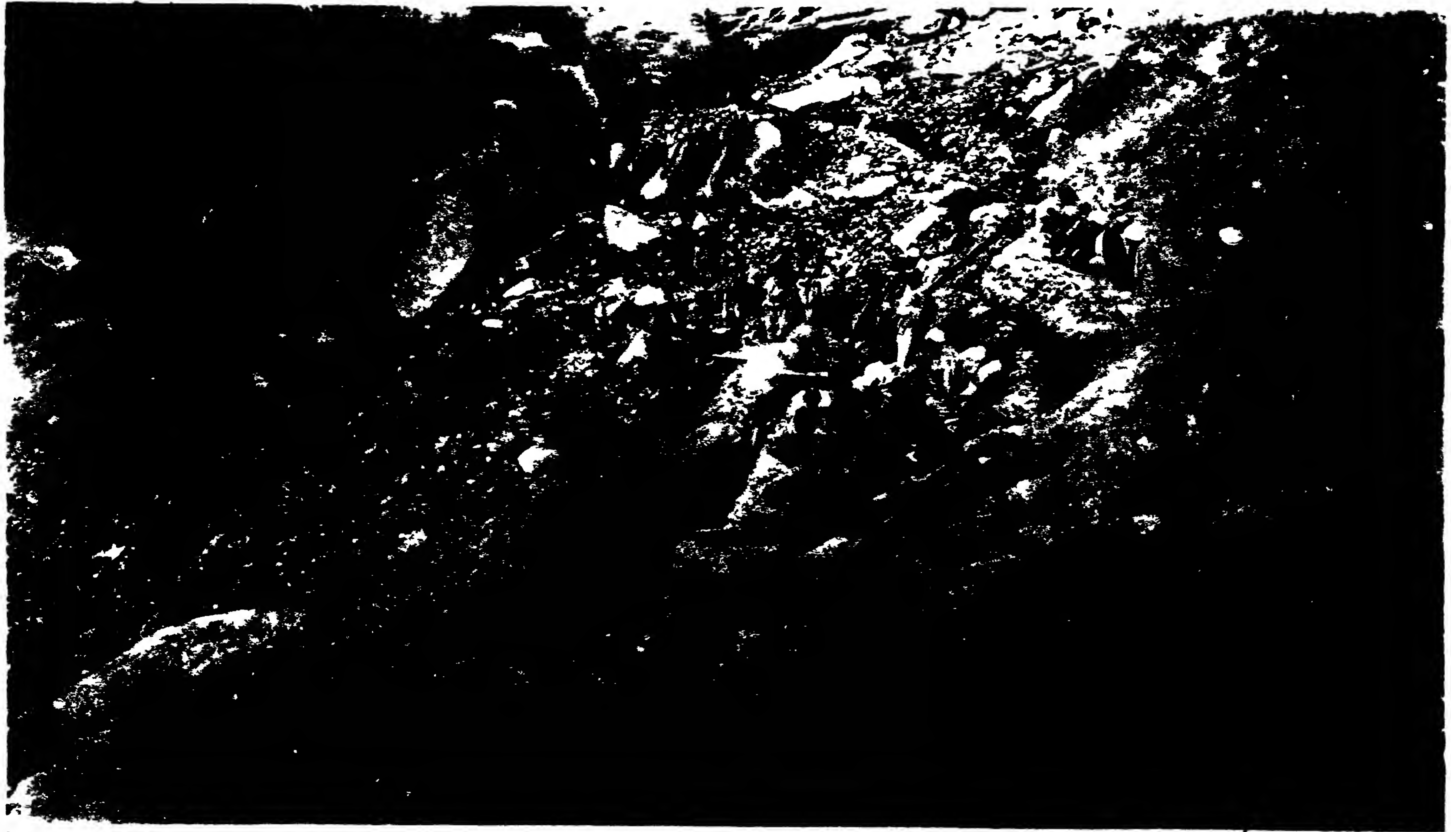

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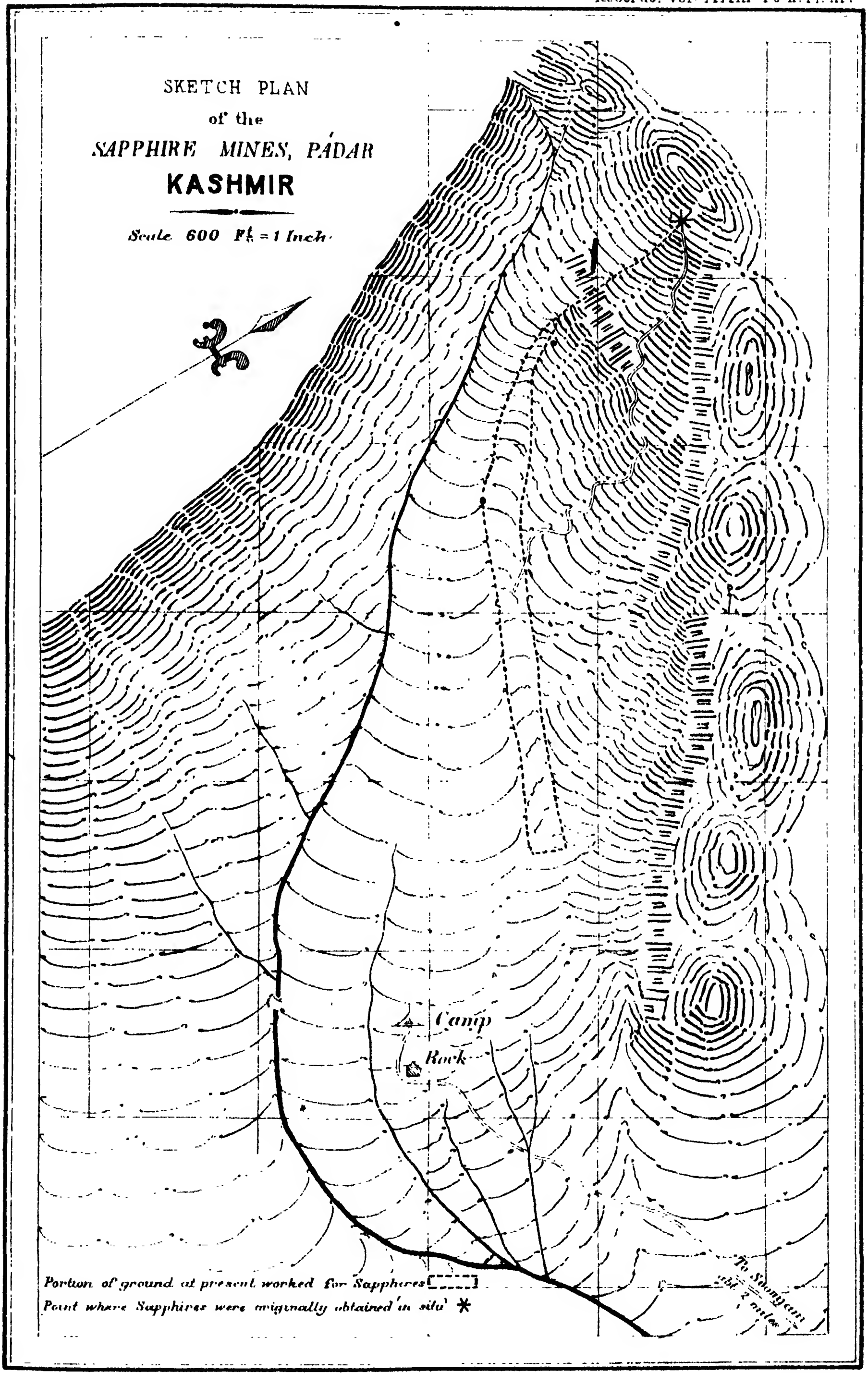
Survey of India Offices Calcutta, April 1890.

GEOLOGICAL SURVEY OF INDIA

La Touche

Records. Vol. XXIII Pt. II. Pl. III.



SKETCH PLAN
of the
SAPPHIRE MINES, PÁDAR
KASHMIR

Scale 600 Ft = 1 Inch

Portion of ground at present worked for Sapphires ☐

Point where Sapphires were originally obtained in situ *

Aminullah.

speaking of the mineral wealth that might be brought to light by properly-conducted prospecting, it does not seem to be generally taken into consideration that the natives of the country have for ages had good opportunities of discovering what minerals the hills contain, and that as a rule they have shown themselves fully capable of making use of their opportunities. I think that I am not far wrong in saying that in very few instances in India have useful minerals been discovered in localities that were unknown to the natives, and in which the ores had not been worked by them at one time or another. Even the more uncivilised hill tribes are more or less well acquainted with the minerals their hills contain, and are by no means in the condition of the Blacks of Australia or the Bushmen of Southern Africa, in whose country the European prospector has found so great a field for his energies. To take a single instance: the Khasis of Assam, who till the beginning of the present century had hardly felt the influence of Western civilization, have for ages obtained their iron from an ore which occurs as minute grains of magnetite disseminated in the granite of their hills. Many a highly-trained European geologist might justly have been sceptical as to the possibility of obtaining a productive iron ore from granite, and would very possibly have passed the rock over as being utterly useless for such a purpose. Yet the Khasis discovered the mineral, and in all parts of the hills ancient heaps of slag testify to the use they made of their discovery; moreover, they obtained the ore by a process which was ingenious and even scientific—in fact, a kind of hydraulic mining somewhat similar to the latest process devised for obtaining gold in California. Can it be doubted that if any other useful minerals existed in their hills, the Khasis would not have found and worked them long ago? Similarly, in Kashmir, any mineral deposits that exist are probably well known to the natives, and, if useful, are already worked, and these are not of any great importance. Even the common minerals, coal and iron, are not found in any large quantity, and where they do occur, are poor in quality. Accident may bring to light the presence of some of the rarer minerals, as in the case of the sapphires, but even the most energetic and intelligent prospector might spend years among the mountains before making such another discovery.

CALCUTTA, 1889.

The supposed Matrix *of the* Diamond *at* Wajra Karur, Madras; *by* PHILIP LAKE, B.A., *Geological Survey of India.* (With one plate.)

Wajra Karur is a small village in the district of Anantapur, lying about 10 miles south of the junction between the Southern Mahratta and Madras Railways at Guntakal. It has long been noted for the diamonds found in the neighbourhood, but until a few years ago no serious attempt seems to have been made to discover the original source from which these diamonds were derived. It was then found that at Wajra Karur there was a peculiar rock presenting some resemblance to the matrix of the diamond at Kimberley; and this rock has since been extensively worked, but apparently, with indifferent success.

The mode of occurrence of this supposed matrix of the diamond has been described by Mr. R. B. Foote,[1] who states that it forms a neck rising through the highly epidotic granite gneiss of the neighbourhood. The precise nature of the rock has not yet been accurately determined, chiefly on account of the great alteration it has undergone.

The neck is made up of a decomposed greenish rock, rough and earthy-looking, and very friable. A number of fragments of harder rock, some rounded, some angular, are included in the neck. Some of these fragments are gneiss and felsite, evidently derived from the surrounding country rock; but others are more like portions of the original rock less altered than the rest.

Numerous small veins and sheets of calcite penetrate the rock, and the earthy part effervesces with hydrochloric acid.

Leaving out of consideration, for the present, the harder included fragments, the main mass of the neck consists of a greenish earthy ground, in which lie small porphyritic grains of a dark-brown mineral. These dark grains at first sight appear to be talc pseudomorphous after augite. They have a greasy lustre and soapy feel, and a tolerably well developed cleavage. The hardness is 1. Many of the grains are prismatic in form, and the prism is sometimes terminated by two faces inclined to each other; but all the faces are very badly defined.

The talc-like mineral was examined by Behrens'[2] microchemical methods (with hydrofluoric acid, &c.) for potassium, calcium, and magnesium; and was found to contain only calcium and magnesium, the latter in larger quantity than the former. By the ordinary chemical methods, it was proved to contain much aluminium, a little iron, and a considerable quantity of combined water. It also contains a small amount of carbonic acid. The presence of so much aluminium as was found proves that the mineral is not a talc or serpentine.

The rock is too soft to yield a thin section for microscopic examination; but a rather thick section showed that it is almost entirely made up of small grains of the talc-like mineral. These small grains are usually more or less oval or circular in shape, and are often surrounded by a border of earthy matter. Some of the grains, however, are more crystalline in form, and show two sets of cleavages like those of augite. The polarisation is indefinite, and the mineral is probably a mixture and not a definite compound.

A little calcite, both in grains and veins, and a very little magnetite, were found to be present.

An analysis of a small portion of the rock (free from included fragments) gave—

$Si\,O_2$	44·73	per cent.
$Al_2\,O_3$	12·83	,,
$Fe_2\,O_3$	4·42	,,
$Ca\,O$	10·35	,,
$Mg\,O$	15·99	,,
$C\,O_2$	2·85	,,
$H_2\,O$ (combined)	9·07	,,
	100·24	,,

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[1] Rec., G. S. I., XIX, p. 109; XXII, p. 35.

[2] Mikrochemische Methoden zur Mineralanalyse. Amsterdam, 1881.

Subtracting the amount of carbonate of lime corresponding to 2·85 per cent. of CO_2, the remainder must represent very closely the composition of the mineral forming the greater part of the rock.

Included fragments.

Many of the fragments of harder rock included in the neck are clearly derived from the surrounding gneiss; but others are quite different from any rocks occurring anywhere in the neighbourhood. These are therefore most likely portions of the original rock less altered than the rest, and several microscopic sections of them have been cut.

In two of these sections the rock was found to be made up chiefly of chlorite with strong pleochroism. The plane of section is usually oblique to the cleavage, and consequently the laminæ of chlorite overlap one another; but in some parts of the slide the plane of section is at right angles to the cleavage, and the chlorite appears fibrous. The polarisation colours are chiefly dull shades of blue.

Besides the chlorite there is a considerable quantity of augite present, mostly in small prisms. A few larger crystals occur, and these appear to be made up of a number of individuals similar to the small prisms. Sometimes the larger crystals are partly broken up, giving rise to a confused mass of these smaller individuals. When the section is examined under a high power without a cover glass, the augite is found, in some cases, to be interlaminated with the chlorite. This is not so well shown when the section is mounted in balsam.

There is a small amount of secondary felspar in minute grains filling up the interstices in the chlorite. As a rule no cleavage is visible and no twinning, and it is only by the use of convergent polarised light that the felspar can be distinguished from quartz. In every case in which the axial figures were visible it was found that the mineral was biaxial. In a very few of the grains twinning is well shown. This felspar, as is so often the case with secondary felspar,[1] is perfectly clear and limpid.

A few small crystals of olivine occur imbedded in the chlorite. These crystals are only altered to a slight extent along the cracks, and otherwise are perfectly fresh. On treatment with dilute hydrochloric acid the olivine decomposed, leaving a pale-greenish gelatinous residue.

Amygdaloids are found in these sections, but are not numerous. They have a dark-brown border and a dark-brown centre, with a lighter-brown zone between.

Other sections show in general the same minerals, but the relative proportion of the minerals varies. In some there is more augite, in others more felspar, and there is usually less chlorite. The chlorite has evidently been formed by alteration of the augite.

Some of the felspar is primary, and this has always been almost completely converted into kaolin; but it still shows the twin lamellæ, which are frequently faulted and sometimes bent.

In some cases a vein of augite given off from a crystal lying near, penetrates a fault fissure in the felspar (see plate). The rock has evidently been subjected to great strains which broke the felspar crystals and caused the augite to *flow* into the nearest cracks. This must have taken place subsequently to the crystallisation of the felspar and the development of the twinning.

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[1] Compare the altered parts of the Scourie dyke. Teall, Q. J. G. S., XLI, p. 139.

In other cases the augite is dragged out into irregular bands, and in all cases it shows evident signs of having been subjected to great strains.

The primary felspar of the section figured was examined for alkalies and alkaline earths by both Boricky's and Behrens' microchemical methods. Only a small amount of sodium was found, but the felspar is too much decomposed to allow us to conclude from this that it was originally a pure soda felspar.

In one section a few crystals of hornblende were found, but in the other sections hornblende was entirely absent.

The included fragments that cannot be referred to the country rock are therefore composed mainly of plagioclase and augite and their alteration products. A plagioclase augite rock might very readily yield on alteration a rock having the same chemical composition as the earthy part of the Wajra Karur neck, and it is therefore highly probably that these included fragments are less altered portions of the original rock forming the neck.

Comparison with the Kimberley rock.

The "matrix of the diamond" at Kimberley, as described by the late Professor Carvill Lewis,[1] is serpentinous, the original rock being composed chiefly of olivine. It was a true peridotite without felspar.

The Wajra Karur rock is not serpentinous, and from the large amount of alumina in it, it cannot have been derived from a rock like *Kimberlite*. It has been formed by the alteration of a basic rock, but not of a peridotite.

Age of the Wajra Karur rock.

The dykes of the granite gneiss region of Bellary and Anantapur are, so far as they have yet been examined, of two kinds, one hornblendic and the other augitic, both containing plagioclase. Some of these dykes are pre-Dharwar in age and others are Dharwar or post-Dharwar; but how far the difference of age corresponds with the difference of composition is as yet unknown. In some cases at least, the plagioclase-augite dykes are of post-Dharwar age.

To the east of the Bellary-Anantapur country, in the Kadapah and Karnul basin, there is an extensive development of augite-bearing eruptive rocks.[2] Some are intrusive and others contemporaneous. All the contemporaneous flows occur in the Cheyair group of the Kadapahs, and none of the intrusive rocks extend into higher beds, so that probably all of them belong to this horizon.

It is probable that there are two series of plagioclase-augite rocks, *viz.*, the post-Dharwar, pre-Kadapah dykes, and the Kadapah trap-flows. To which of these the Wajra Karur rock belongs, is uncertain. Olivine has been found in one of the Kadapah flows and not hitherto in any pre-Kadapah rocks; but the amount of olivine in the Wajra Karur rock is very small, and it would be unsafe to base any speculations on its presence.

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[1] Rep. Brit. Assoc., 1887, p. 720. See also Rec., G. S. I., XXII, p. 48.

[2] W. King., Mem., G. S. I. VIII, p. 195 *et seq.* Sections have been cut of the specimens of these flows in the Museum, and all of them have been found to contain augite.

GEOLOGICAL SURVEY OF INDIA.

Luke.

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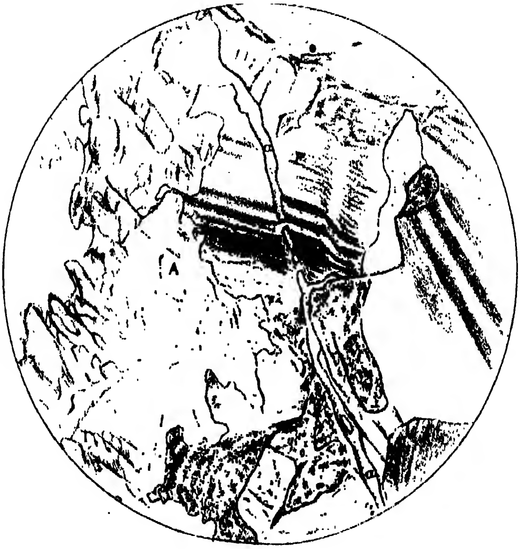

WAJRA KARUR ROCK

Section of one of the harder fragments

A *Augite. a Vein of augite given off from A – With polariser alone.*

F. *Felspar with bent and faulted twin lamellae – Between crossed Nicols.*

Notes *on the* Sonapet Gold-field; *by* FRITZ NOETLING, Ph.D., *Geological Survey of India.* (With two Plates.)

I.—TOPOGRAPHY.

The area to be described is situated in Chutia Nagpur, in the south-east corner of the Lohardagga district. Under present conditions it is far from any way of communication, as the nearest railway line is not less than 70 miles distant from it as the crow flies. It is, however, stated that the Bengal-Nagpur railway will pass within 15 miles south from the Sonapet river; but it is quite certain that a considerable time will elapse before the railway line is pushed so far to the south as to be in the neighbourhood of the gold-fields. For the present the isolated situation of the gold-fields must be taken into consideration, and it must be kept in mind that every piece of machinery will have to go by the expensive land route.

As a matter of convenience I divide the area examined by me into two parts, which will be dealt with separately. The northern part is limited by the Karkari river in the north, the district boundary in the east, the northern slope of the lofty Abunkabi hills in the south, and by a small feeder of the Karkari in the west.

The southern part includes the Abunkabi hills and the Sonapet valley.

(*a*) The northern area consists mostly of open country, paddy-fields for the greatest part. Isolated hills covered with jungle rise frequently abruptly from the surrounding plains. These hills can, however, only be considered as detached parts of the higher ranges to the south. The northern slope of the Abunkabi hills is steep and much intersected by numerous ravines which discharge their water in a northerly direction, so that the streams taking their origin in such ravines eventually join the Karkari river. The country therefore slopes, very slowly, however, from the foot of the hills in a northern direction; that is to say, towards the Karkari, which flows at some miles to the north nearly parallel with the hills. It is therefore perfectly clear that all such alluvial deposits as river-sands, etc., which are to be found within the limits above described must come from the south. The accompanying outline plan (Plate I) shows that all the streams running through this tract drain only that particular part of the hills which lies north of the central range. It may therefore be said that all the river-deposits, except, of course, those of the Karkari itself, came from the hill tract north of the central range; and any gold therein found must have been derived from the same tract.

(*b*) The southern area includes the Abunkabi hills and the Sonapet valley. The Abunkabi hills may be divided into three nearly parallel ranges. The central range, which rises to about 2,800 feet on an average, forms a kind of semi-circle open towards the south-east. The northern branch extends far beyond the limits of the area examined, while the southern branch, which is much shorter, terminates abruptly in a prominent hill. The southern range, which is considerably lower, rising not more than 2,000 feet, follows closely the direction of the central range along its inner side. Its northern branch, which also extends far beyond the limits of our area, is distinctly separated from the central range by a deep valley gradually widening towards the east; while the central and southern parts, which are not so well separated, seem to form with the central range one huge mass of hills, terminating in the Sursi Tulsi hill.

The northern range runs parallel to the north branch of the central range, with which it is connected in its eastern end by a flat, plateau-like depression, which, however, deepens into a narrow valley towards the west.

The valley formed by the semi-circular turn of the central range is known as the Sonapet valley: it is of a peculiar basin-like shape, the hills sloping towards its centre from every side except from the east, where it has an outlet. The southern hill ranges come, however, here so close up to their northern part as to form a comparatively narrow gate of not more than 1¾ miles in breadth, through which the Sona river runs. The valley, as thus defined, has an extreme length of 7½ miles, its greatest breadth being 3 miles; as it narrows, however, considerably in its upper part, its total area can only be taken as 16·6 square miles, of which 1·3 square miles belong to the Singbhoom district.

The main drainage is represented by the Sona stream flowing in the longitudinal axis of the valley in an east-south-east direction. The Sona receives its feeders from north, west, and south; but it must be particularly mentioned that its main feeders are two streams coming from the north, which take their origin between the central and the southern range, and after cutting narrow ravines through the last one, deposit their detritus in front of them in the Sonapet valley. The western feeders of the Sona are far less considerable, and from the south only a few insignificant streams discharge their water into it. Taken all in all, the upper part of the Sona, of 7½ miles in length, drains a total area of not less than 50 square miles of hilly and jungly country, which is quite sufficient to provide for a large supply of water all the year round.

From this description it will be seen that all the gold, as far as it is found in the alluvial deposits of the Sonapet valley, must be traced to strata within the area bounded by the central range, and must therefore come from reefs. or from the disintegration of the country rocks.

II.—GEOLOGY.

(a) *General Geology.*

The strata developed in the country just described belong to the gneissic, transition, and alluvial formations; the latter is, however, only the result of the disintegration of the first one, covering it in the shape of red clays nearly all over the country, while in the shape of river-sands it is only developed in the valleys. The two groups thus given may therefore be considered separately.

1. The gneissic formation.

The rocks belonging to this formation exhibit no peculiarity worth mentioning. They are well displayed in the northern area, and it is highly probable that they occur again in the Sonapet valley and also on the southern side of the southern hill range. As they are, however, evidently of no importance for practical purposes, they may only be mentioned here.

2. The transition series.